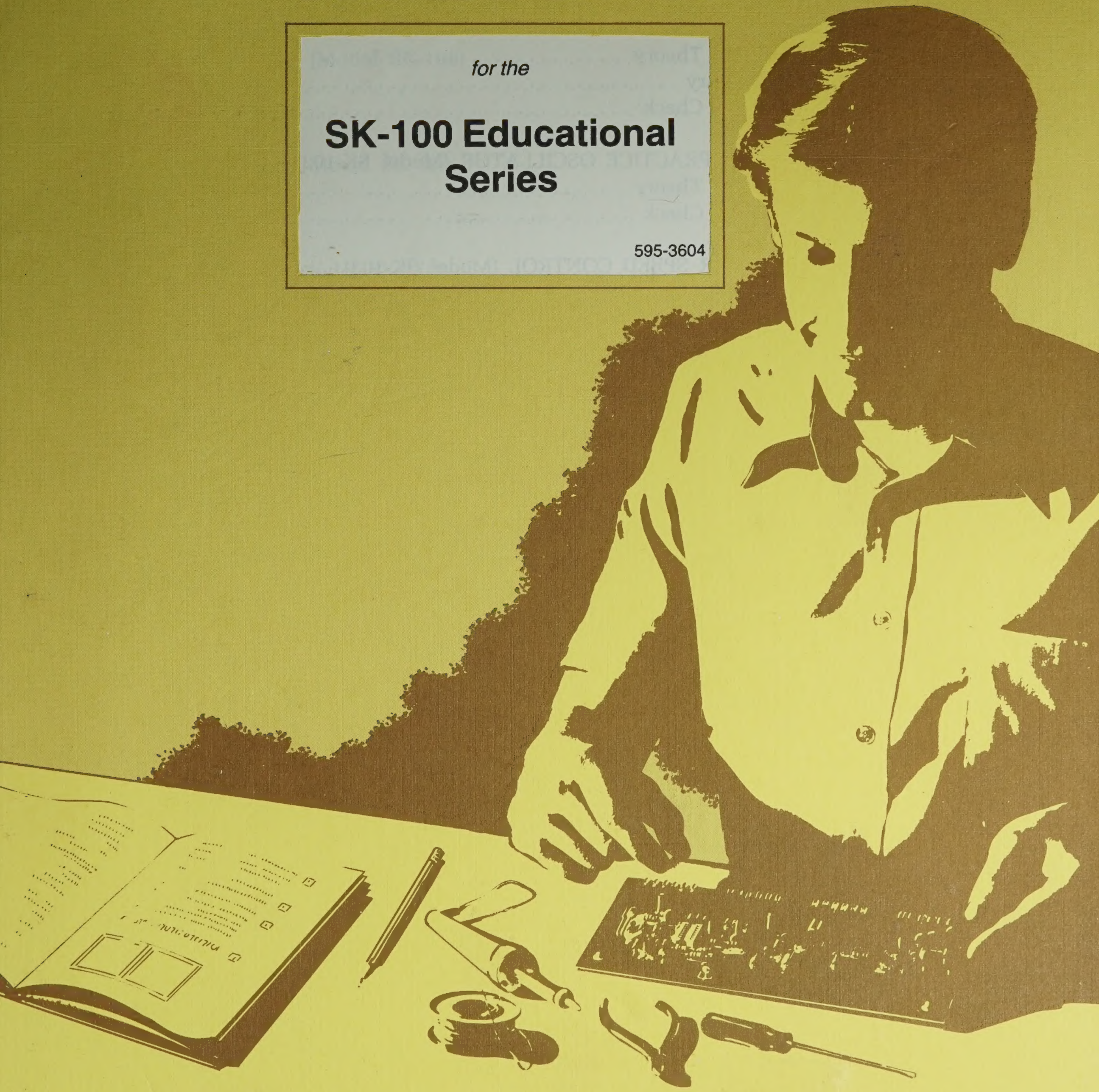
HEATHKIT® MANUAL

for the

SK-100 Educational Series

595-3604



HEATH COMPANY • BENTON HARBOR, MICHIGAN

for the

SK-100 Educational Series

595-3604

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Introduction

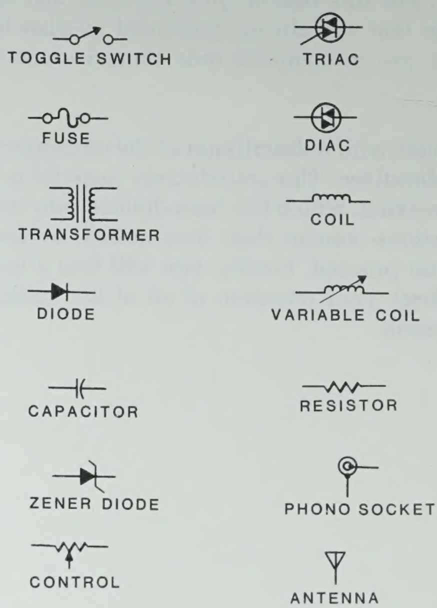
This Manual is designed to go with the Heathkit Models SK-101 through SK-111 kits. It is more than just a description of circuit operation. As you complete each lesson; you will actually learn something about electronics.

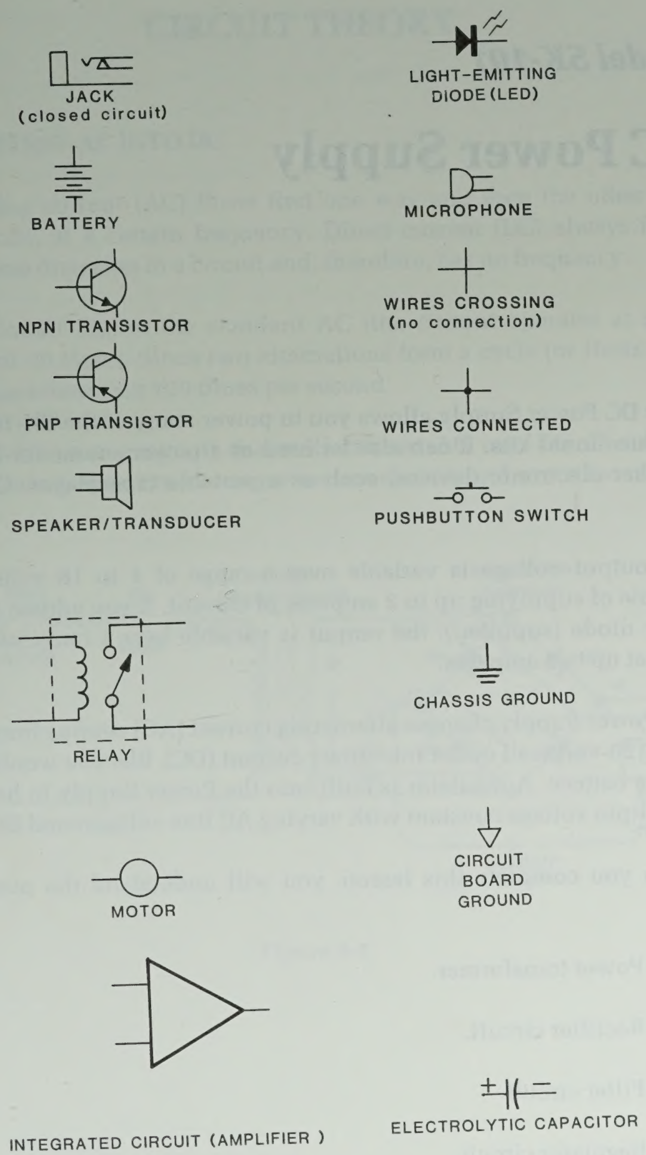
Each lesson is complete in itself, so it is not necessary to proceed in any specific order. For this reason, you may find that some lessons contain information that was already presented in other lessons. This duplication allows you to complete only those lessons that interest you.

The lessons each start with a description of the corresponding kit and a list of learning objectives. This introductory material is followed by the actual lesson material, which has been divided into small sections. Many of these sections contain their own quizes, so you can check your learning as you proceed. Finally, you will find a test at the end of the lesson to check your retention of all of the material that was presented in that lesson.

Electronic Symbols

The symbols used throughout this Manual are shown below. You may find that these symbols vary somewhat when you compare them to other Manuals, but we have tried to be consistent throughout this Manual.




JACK
(closed circuit)
LIGHT-EMITTING
DIODE (LED)
BATTERY
MICROPHONE
NPN TRANSISTOR
WIRES CROSSING
(no connection)
PNP TRANSISTOR
WIRES CONNECTED
SPEAKER/TRANSDUCER
PUSHBUTTON SWITCH
RELAY
CHASSIS GROUND
MOTOR
CIRCUIT
BOARD
GROUND
INTEGRATED CIRCUIT (AMPLIFIER)
ELECTROLYTIC CAPACITOR

Model SK-101

DC Power Supply

Your DC Power Supply allows you to power many of the SK-100 series of educational kits. It can also be used as a power source for a variety of other electronic devices, such as a portable tape player, CB radio, etc.

The output voltage is variable over a range of 4 to 18 volts and is capable of supplying up to 2 amperes of current. If you add an optional zener diode (supplied), the output is variable over a range of 4 to 14 volts at up to 3 amperes.

The Power Supply changes alternating current (AC) coming from a standard 120-volt wall outlet into direct current (DC), like you would obtain from a battery. A regulator is built into the Power Supply to help keep the output voltage constant with varying AC line voltages and DC loads.

When you complete this lesson, you will understand the purpose of a:

1. Power transformer.

2. Rectifier circuit.

3. Filter circuit.

4. Regulator circuit.

CIRCUIT THEORY

CONVERTING AC INTO DC

Alternating current (AC) flows first one way and then the other way in a circuit, at a certain frequency. Direct current (DC) always flows in the same direction in a circuit and, therefore, has no frequency.

In the United States, the standard AC line current operates at a frequency of 60 Hertz. Since two alternations form a cycle (or Hertz, Hz), AC changes direction 120 times per second.

Figure 1-1 shows a circuit that will convert AC into DC. The major components in the circuit are a power transformer and a rectifier circuit.

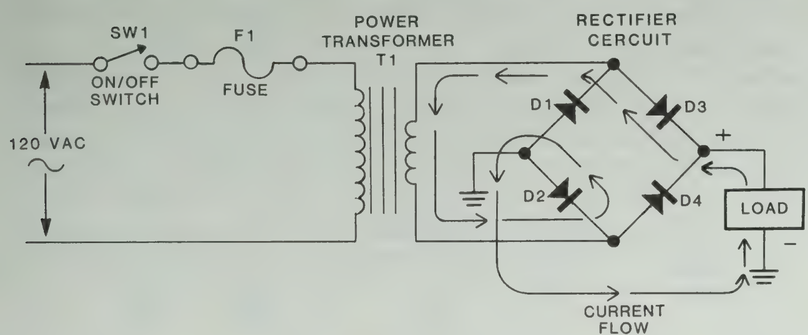


Figure 1-1

After the AC line current passes through the on/off switch and the protective fuse, the line voltage is applied across the input, or primary, winding of power transformer T1. A power transformer allows you to change the amplitude (amount) of an AC voltage into a different voltage, or voltages. The number of turns of wire on the primary versus the number of turns on the output, or secondary, winding determine whether the transformer will increase or decrease the primary voltage. Since the power transformer in your Power Supply has less turns on the secondary than it has on the primary, it reduces, or "steps-down," the voltage from approximately 120 volts to approximately 18 volts.

After the AC voltage is reduced, it must be converted into DC. Diodes D1 through D4 form a full-wave rectifier that performs this AC-to-DC conversion. During the half cycle that the AC current is flowing from the top of the secondary winding toward the bottom (see Figure 1-1), it passes through diode D2, circuit ground, the load (external circuit), and back to the power transformer through diode D3. Diodes are "one-way" devices that allow current to flow through them in only one direction. During the next half cycle when the current is flowing in the other direction (see Figure 1-2), it passes through diode D1, circuit ground, the load, and back through diode D4. Since the junction of diodes D3 and D4 is always positive with respect to circuit ground, it is considered as a DC voltage.

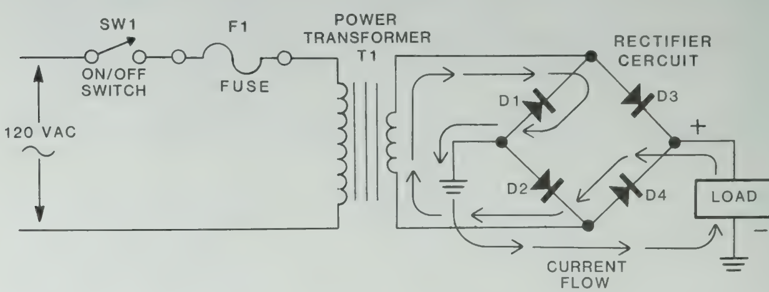


Figure 1-2

Quiz

1. AC in the United States changes direction ________ times per second.

2. DC flows **both/the same** direction(s) in a circuit. (circle one)

3. A power transformer allows you to change the amount of an AC voltage into a ____________ voltage that you require.

4. The power transformer in your Power Supply **steps-up/steps-down** the line voltage. (circle one)

5. In the circuit shown in Figure 1-1, diodes D1 through D4 perform a ________ -to- ________ conversion.

6. The junction of diodes D3 and D4 is always **positive/negative** with respect to circuit ground. (circle one)

FILTERING

Although the output of the rectifier circuit is similar to DC, it does have some AC ripple on it. This ripple is caused by the transition that occurs when the AC changes directions. The addition of capacitors C1 and C2 and resistors R1 and R2 form a filter circuit (see Figure 1-3) to help smooth out most of the AC ripple that may be present.

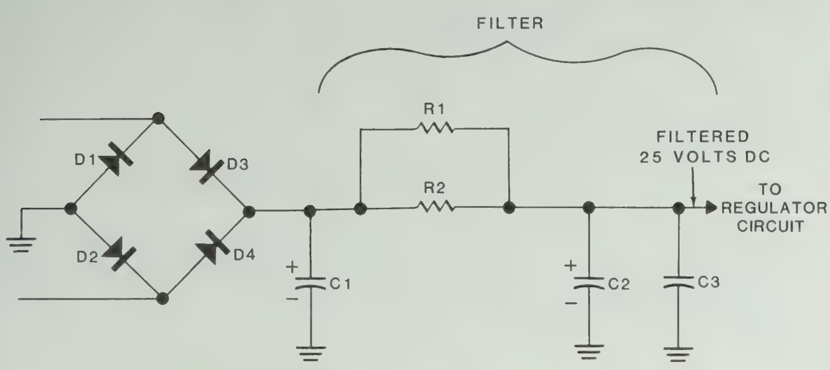


Figure 1-3

Since capacitors take time to charge and then discharge, they tend to smooth out changes. Capacitor C1 performs some smoothing action and capacitor C2, which is isolated from C1 by resistors R1 and R2, performs additional filtering. The combination of the time delay effect of capacitors C1 and C2 and the voltage drop across resistors R1 and R2 make the DC essentially flat.

Large-value electrolytic capacitors, such as those used in your Power Supply also help to increase the voltage applied to them. In a full-wave rectifier circuit, the DC voltage increase is approximately 1.4 times the AC voltage you start with. As we mentioned earlier, the output of the power transformer was approximately 18 volts AC. After rectification and filtering, however, you end up with approximately 25 volts DC.

Although it is not directly a part of the filter described above, capacitor C3 is also a part of the overall filter circuit. This capacitor, due to it's small value, helps stabilize the circuitry and reduce high-frequency noise before the DC is applied to the regulator circuit described next.

Quiz

1. In the circuit shown in Figure 1-3, components ________, ________, ________, and ______ form a filter circuit.

2. Since capacitors take time to charge and discharge, they tend to ____________ out changes.

3. Capacitor C3 helps ____________ the circuitry and ____________ high-frequency noise.

REGULATOR CIRCUIT

Refer to Figure 1-4 while you read the following information.

The final circuit in your Power Supply is called the "regulator." This circuit helps keep the output voltage of the Power Supply constant with varying loads and line voltages.

A three-terminal adjustable regulator IC (integrated circuit) forms the heart of this circuit. The regulator used in your Power Supply at U1 is capable of providing a constant voltage between 4 and 18 volts DC.

Resistors R4 and R5 and control R3 form a voltage divider that is connected between the output of the regulator and ground. Current flowing through the voltage divider causes voltage drops across each resistor that is proportional to its resistance value. A connection from the junction point of R3 and R5 to the adjustable input of the regulator allows the regulator to monitor the output voltage. Since control R3 is connected in the divider string, it allows you to adjust the regulator output by varying the voltage at the adjustable input.

Diodes D5 and D6 are included in the circuit to protect the IC from voltage spikes caused by sudden changes in the load. Capacitor C4 provides additional filtering, circuit stability, and improved transient response. Diode D7 is an optional component which prevents the output voltage from exceeding 14 volts DC. When this diode is installed, however, the available current increases from 2 to 3 amperes.

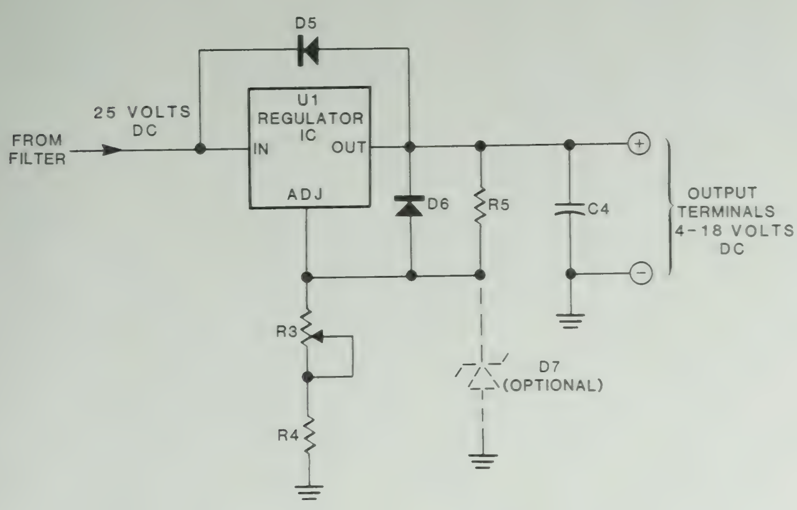


Figure 1-4

Quiz

1. The ____________ circuit helps keep the output voltage of the Power Supply constant with varying loads and line voltages.

2. A three-terminal adjustable ____________ IC forms the heart of the regulator circuit.

3. In the circuit shown in Figure 1-4, control R3 allows you to adjust the output of the voltage at the ____________ input of the IC.

4. Diodes D5 and D6 protect the IC from ____________ ____________ caused by sudden changes in the load.

5. Optional Diode D7 prevents the ____________ voltage from exceeding 14 volts DC.

SUMMARY

Figure 1-5 (fold-out from Page 121) shows the entire circuit of your Power Supply. The circuit consists of a power transformer, a full-wave rectifier circuit, a filter circuit, and a regulator circuit.

The Power transformer changes the line voltage into the desired voltage, the rectifier circuit changes AC into DC, the filter circuit smooths out the DC, and the regulator helps hold the DC voltage constant during load and line voltage changes.

LESSON CHECK

1. AC in the United States changes direction ______ times per second.

2. DC flows **both/the same** direction(s) in a circuit. (circle one)

3. The power transformer in your Power Supply **steps-up/steps-down** the line voltage voltage. (circle one)

4. In the circuit shown in Figure 1-5, diodes D1 through D4 perform a ________ -to- ________ conversion.

5. The junction of diodes D3 and D4 is always **positive/negative** with respect to circuit ground. (circle one)

6. The __________ circuit helps smooth out any ripple that may be present after rectification.

7. When large electrolytic capacitors are used in the filter circuit, the DC voltage at the output of the filter circuit is **higher/lower** than the AC voltage applied to the rectifier circuit. (circle one)

8. The __________ circuit helps keep the output voltage of the Power Supply constant with varying loads and line voltages.

Model SK-102

Code Practice Oscillator

Even though your Code Practice Oscillator is a very simple device, it serves two useful purposes. After you have it assembled and operating, you can use it to learn and then become proficient in the International Morse Code. In addition, as part of this lesson, you will learn how the circuit works.

The heart of your Code Practice Oscillator is a type 555 timer IC. This IC can produce oscillations (electronic vibrations) that occur as fast as a fraction of a second to as slow as an hour. The 555 IC has the advantage over a transistor circuit of being inexpensive, small (8-pin IC package), and requiring a minimum of additional external components.

Since the 555 timer IC can be used in a monostable (one-shot) mode and an astable (free-running) mode, it has many applications. Some of these are time-delay generation, sequential timing, linear sweep generation, precision timing, pulse generation, pulse shaping, missing pulse detection, pulse width modulation, and pulse position modulation.

When you complete this lesson, you will be able to:

1. Properly connect a 555 timer IC to generate oscillations.

2. Explain the difference between monostable and astable.

3. Change values in the circuit to change the oscillation rate.

4. Properly connect an NPN transistor so that it will conduct.

CIRCUIT THEORY

The object of this lesson is to show you how to use a 555 timer IC without becoming too technical. For this reason, the circuit will be explained as if the IC were a "black box." The various pins are described first, followed by a brief explanation of the external circuitry.

Refer to Figure 2-1 while you read the following information.

Pin 8 (Vcc) — Connects to the positive (+) terminal of a power source, such as a battery. It supplies the DC voltage required by the internal circuitry of the IC. This should be between 4-1/2 and approximately 18 volts DC, depending upon the particular brand of IC.

Pin 1 (ground) — Connects to the negative (−) terminal of a power source and the common line of the circuitry. It provides the return for the internal and external circuitry.

Pin 3 (output) — Connects to an external circuit that uses the oscillations produced by the timer. In the case of your Code Practice Oscillator, it connects to a speaker so the oscillations are audible.

Pin 5 (control) — Provides access to a reference point inside the IC. This allows you to modify the timing period or reset one of the internal circuits. When it is not used, such as in your Oscillator, it should be connected to ground through a capacitor. This capacitor helps reduce circuit noise.

Pin 2 (trigger) — Connects to an external timing circuit to start the timing operation.

Pin 6 (threshold) — Connects to an external timing circuit to stop the timing operation.

Pin 4 (reset) — Allows you to reset the timing operation. This connection allows you to override the normal timing operation.

Pin 7 (discharge) — Connects to the external timing circuit to discharge the capacitor in that circuit.

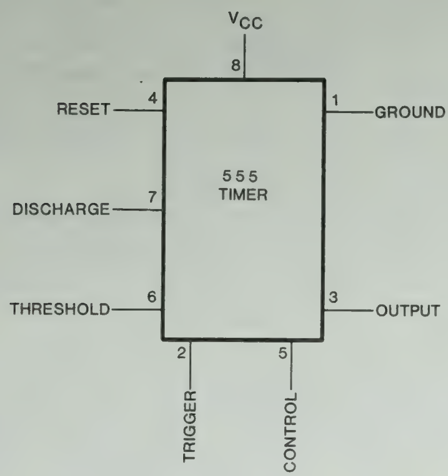


Figure 2-1

Refer to Figure 2-2 while you read the following information.

Resistors R1 and R3, control R2, and capacitor C1 are connected across the power source to form a voltage divider. As capacitor C1 charges toward the supply voltage, it will reach the trigger point of the IC at pin 2. The rate at which the capacitor charges is directly related to the values of the components in the divider.

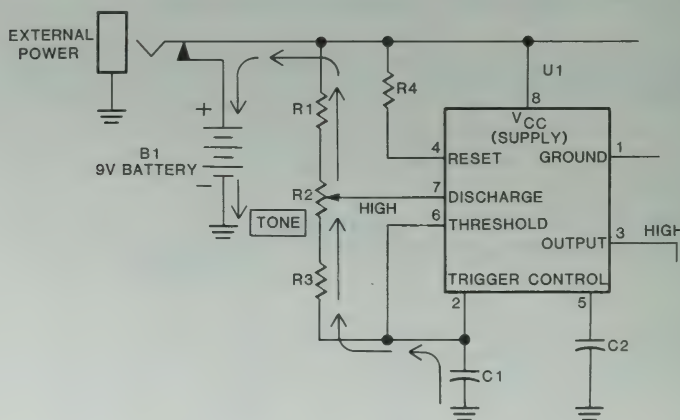


Figure 2-2

Prior to the time that the IC triggers, output pin 3 and discharge pin 7 are high (if SW1 in Figure 2-3 is held down; nothing happens if SW1 is open). As soon as the IC triggers, the output pin and the discharge pin go low (see Figure 2-3). This acts as a short across capacitor C1 and forces it to discharge through resistor R3, part of control R2 and the IC. The rate of discharge depends upon the values of R3, C1, and the setting of R2.

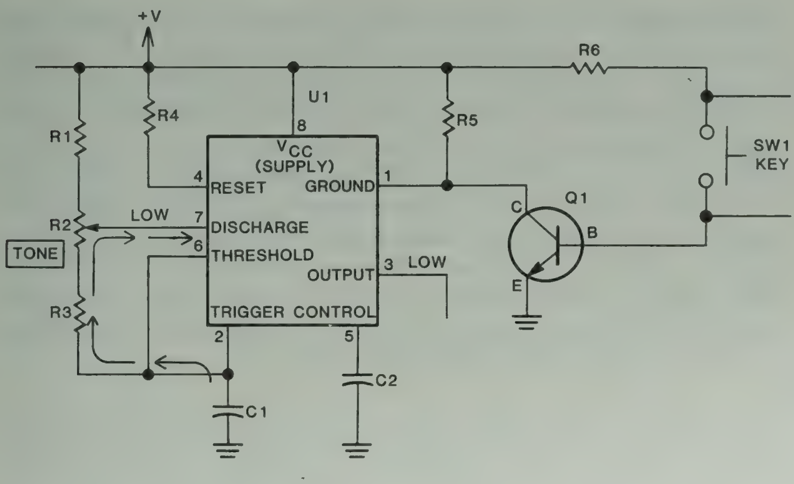


Figure 2-3

When the capacitor discharges to the threshold point of the IC at pin 6, output pin 3 and discharge pin 7 will again go high. the process will then repeat until you remove power from the circuit, or release SW1.

With the output of the IC continually alternating between high and low, you essentially have an oscillator whose frequency depends upon the values of R1, R2, R3, and C1. Since the oscillator is free running, it is operating in the astable mode. A 555 time IC that operates in the monostable mode would change states when it is triggered, wait a predetermined length of time, and then return to the original state.

To oscillate, U1 must have supply voltage applied to pin 8. In addition, pin 1 must be grounded. As you can see, pin 1 goes to ground through transistor Q1. When the transistor is turned off, it acts as an open switch and isolates pin 1 from ground. Before the transistor can conduct, and allow pin 1 to get to ground, certain conditions must be met.

Since transistor Q1 is an NPN type (note that the arrow points away from the base), to conduct, the emitter (E) must be negative, the collector (C) positive, and the base (B) slightly (about 0.7 volt) positive. The collector is positive because it is connected to the positive supply through R5, and the emitter is always negative because it is connected to the negative side of the supply. When switch SW1 is closed, a positive voltage is applied to the base through R6 and the transistor is turned on (see Figure 2-4). When switch SW1 is open, however, no positive voltage is applied to the base and the transistor is turned off (see Figure 2-5). In this circuit, switch SW1 acts as a switch that allows you to turn the oscillator on and off and provides you with the means to "key" the oscillator to produce morse code.

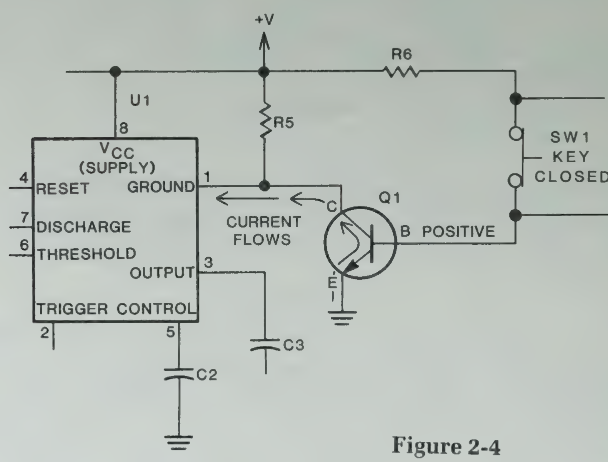


Figure 2-4

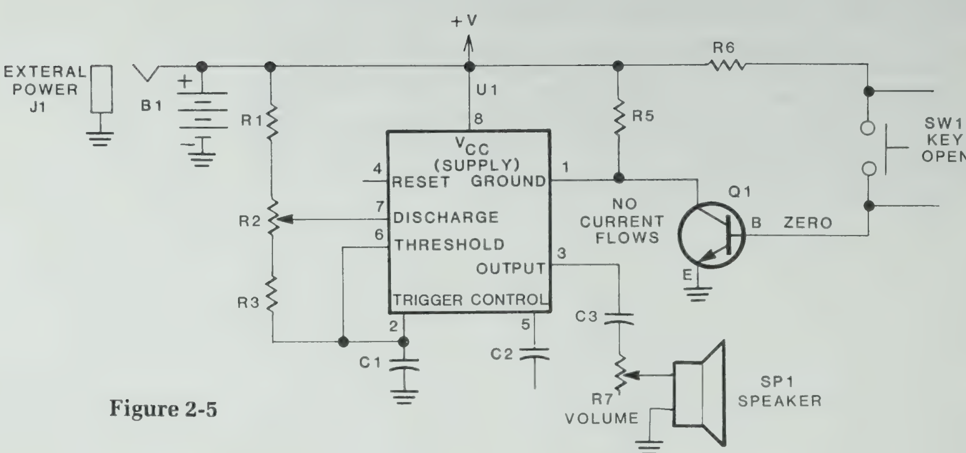


Figure 2-5

Although fixed-value resistors could be used in place of R2, the control allows you to vary the frequency of oscillation over a limited range. You could change the frequency over a wider range by changing the values of the resistors at R1 and R3 and capacitor C1. The nomogram in Figure 2-6 shows the approximate values of the components needed to make the timer operate at different frequencies. NOTE: The resistances shown are for the sum of resistor R1 and half the resistance of R2 plus two times the sum of resistor R3 and half the resistance of R2. This assumes that control R2 is initially set to the center of its rotation. To construct an oscillator that has a frequency of 100 Hz, for example, you could use 100 kΩ resistors at R1 and R3, a 200 kΩ control at R2, and a 0.1 μF capacitor at C1.

The oscillation coming from output pin 3 passes through capacitor C3 and control R7 to speaker SP1 (see Figure 2-5). Capacitor C3 isolates the speaker from the IC, and control R7 allows you to adjust the volume.

Jack J1 allows you to use a battery or an external power supply to power the circuit. When nothing is plugged into the jack, the battery voltage is applied to the IC. When you plug an external supply into the jack, however, the jack automatically disconnects the battery from the circuit and applies the external power to the IC.

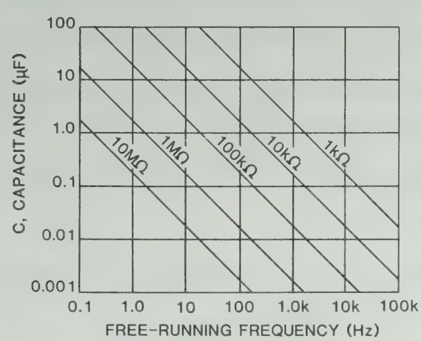


Figure 2-6

LESSON CHECK

Refer back to Figure 2-1 when you answer the following questions.

1. The Vcc pin of the IC connects to the __________ terminal of the power source and supplies the voltage required by the __________ of the IC.

2. The ground pin connects to the __________ terminal of the power source and provides the __________ for the internal and external circuitry.

3. The output pin connects to an external circuit that uses the __________ produced by the timer.

Refer back to Figure 2-2 when you answer the following questions.

4. As capacitor C1 charges toward the supply voltage, it will reach the __________ point of the IC at pin 2.

5. The rate at which capacitor C1 charges is directly related to the values of ________, ________, ________, and ________.

6. The rate of discharge depends upon the values of ________, ________, and the setting of ________.

7. With the output of the IC continuously alternating between high and low, you essentially have an __________.

8. Control R2 allows you to __________ the frequency of oscillation.

9. The timer in your Code Practice Oscillator operates in the **monostable/astable** mode (circle one)

10. To conduct, an NPN transistor must have a ________ voltage on the collector, a ________ voltage on the emitter, and a slightly ________ voltage on the base.

NOTE: Refer to the "Fish Caller" lesson for additional instruction in timer circuits.

Model SK-103

Motor Speed Control

In very simple terms, your Motor Speed Control is a switch that repeatedly turns a motor on and off. The ratio of the off time compared to the on time determines the motor speed. As the off time becomes shorter, the motor speed increases.

The heart of your Motor Speed Control is a device called a triac, a solid-state switch (contains no moving parts). This lesson explains the operation of a triac and how it can be used in a circuit to control motor speed.

When you complete this lesson, you will:

1. Be able to draw the symbol of a triac.

2. Understand how a triac operates.

3. Understand how a diac operates.

CIRCUIT THEORY

TRIACS

Figure 3-1 shows a triac connected in a simple circuit. As you can see, the symbol for a triac is two diodes connected back-to- back with the addition of a gate lead. The gate lead allows you to control whether the triac, which acts as a switch, is on or off. The other two triac leads are labeled terminal 1 and terminal 2, since they act as an anode and a cathode at different times.

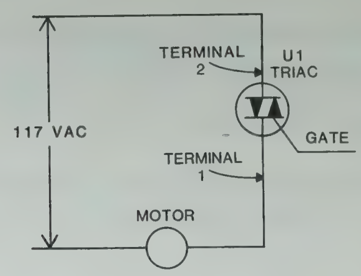


Figure 3-1

When AC (alternating current) is applied to the circuit, it will attempt to pass through the triac in one direction during one- half of the cycle and then the other way during the other half cycle. Depending upon the voltage applied to the gate, however, the current can be either allowed to pass through or it can be stopped.

For current to pass through a triac, the gate voltage must be positive with respect to the lead that is acting as the cathode at a given time. For current to pass through the triac both ways, the gate voltage must change polarity twice during each AC cycle.

Quiz

1. Draw the symbol of a triac.

2. The leads of a triac are referred to as ________, ________, and ________.

3. The ________ lead allows you to control whether the triac is on or off.

4. For current to pass through a triac, the gate voltage must be ________ with respect to the lead that is acting as the cathode at a given time.

5. For current to pass through a triac both ways, the gate voltage must change ________ twice during each AC cycle.

CONTROLLING A TRIAC

As you learned in the first part of this lesson, the gate voltage must change polarity twice during each AC cycle. Figure 3-2 shows you how you can add three components to the circuit to make this happen automatically.

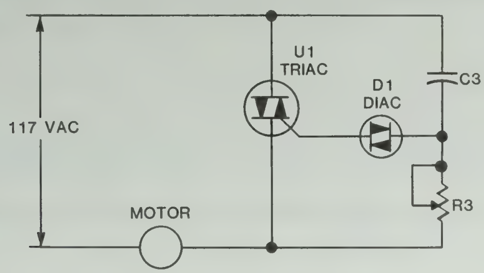


Figure 3-2

When power is first applied to the circuit, no current flows through the triac because there is no voltage on the gate. Capacitor C3, which is in series with control R3, will begin to charge toward the supply voltage. When the charge across the capacitor reaches a certain voltage, one half of diac D1 will conduct, so the voltage is applied to the gate of the triac. This causes the triac to conduct, which allows the motor to run. All of this happens during one half cycle of the AC.

A diac is like two zener diodes that are connected back-to-back. Diacs are specified by the amount of voltage required across them before they will conduct. You could say, then, that a diac is like a voltage-sensitive switch.

During the next AC half cycle, the capacitor charges with the opposite polarity. But since the lead that is connected to the diac is more positive than the other lead (which during this half cycle is connected to the cathode of the triac), the other diode in diac D1 will eventually conduct and apply the voltage to the gate. This again causes the triac to conduct, but in the opposite direction.

A fixed value resistor could be used at R3, but because R3 and C3 form a timing network, the control allows you to vary the charging rate of the capacitor. Depending upon how fast or how slow capacitor C3 charges, the triac may be turned on less often or more often. The less often the triac conducts, the slower will be the motor speed.

Since the current that charges capacitor C3 passes through the motor, it appears the motor will run even when the triac is turned off. This is not the case, however, because the current drawn by the timing network is much too small to operate the motor.

Quiz

NOTE: Refer to Figure 3-2 while you answer the following questions.

1. When the charge across capacitor C3 reaches a certain voltage, one half of diac D1 will ______________.

2. Diacs are specified by the amount of ______________ required across them before they will conduct.

3. Diacs are like a voltage-sensitive ______________.

4. Control R3 allows you to vary the ______________ rate of capacitor C3.

5. When capacitor C3 charges less often, the motor speed will become **faster/slower**. (circle one)

THE COMPLETE CIRCUIT

Although the circuit shown in Figure 3-2 will work, some additional circuitry is required to make it work better. Figure 3-3 shows the complete circuit of your Motor Speed Control.

Fuse F1 is a safety device that opens the circuit in the event too great a load is applied to the circuit, or some other circuit malfunction occurs.

Electric motors and the switching transients of the triac often cause radio frequency interference (RFI). Capacitor C1 and coil L1 form a low-pass filter that helps reduce the RFI entering the AC line.

The R/C network formed by resistor R1 and capacitor C2 was also added as a protective measure. Electric motors produce what is known as a "kickback voltage" when they are turned off. This kickback is caused by the collapsing magnetic field, and could damage the triac. These parts help reduce the kickback voltage to a level that will not cause damage to your Motor Speed Control.

Resistor R2 has been added in series with control R3. This resistor simply provides smoother control of motor speed by allowing the control to operate over a smaller range.

The final circuit that was added is the R/C network formed by capacitor C4, control R4, and resistor R5. Since motors can present widely-varying loads on the circuitry, some method must be implemented to allow you to tailor the circuit to your particular load. The effect of this network is mostly noticeable at slow motor speeds.

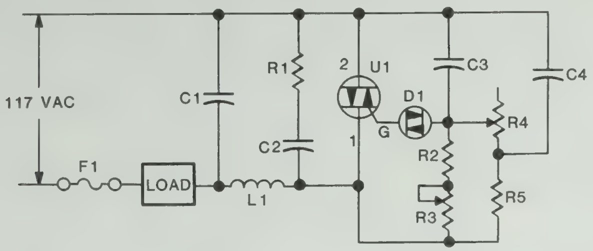


Figure 3-3

Quiz

Refer to Figure 3-3 while you answer the following questions.

1. Electric motors often cause __________ interference.

2. Capacitor C1 and coil L1 form a low-pass filter that helps prevent RFI from entering the ________ line.

3. Electric motors produce what is known as __________ voltage when they are turned off.

4. The effect of the R/C network formed by C4, R4, and R5 is mostly noticeable at **slow/fast** motor speeds.

LESSON CHECK

1. Draw the symbol of a triac:

2. The leads of a triac are referred to as __________, __________, and __________.

3. The __________ lead allows you to control whether the triac is on or off.

4. For current to pass through a triac, the gate voltage must be ____________ with respect to the lead that is acting as the cathode at a given time.

5. Diacs are specified by the amount of ____________ required across them before they will conduct.

6. Diacs are like a voltage-sensitive ____________.

NOTE: Refer to Figure 3-3 when you answer the following questions.

7. When capacitor C3 charges less often, the motor speed will become **faster/slower**. (circle one)

8. Capacitor C1 and coil L1 form a low-pass filter that helps prevent RFI from entering the __________ line.

Model SK-104

1-Watt Audio Amplifier

The heart of your 1-Watt Audio Amplifier is a type LM388 integrated circuit amplifier. The LM388 has the advantage over a transistor circuit of being inexpensive, small (14-pin IC package), and requiring only a few external components.

Some of the applications where you might find this type of amplifier are in AM-FM radios, portable tape players, intercoms, and television sound system.

When you complete this lesson, you will be able to:

1. Properly connect an LM388 IC in a circuit.

2. Change values in the circuit to change the overall available gain.

3. Change values in the circuit to change the frequency response.

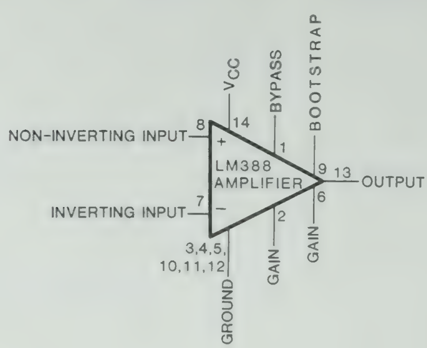


Figure 4-1

CIRCUIT THEORY

The object of this lesson is to show you how to use an LM388 amplifier IC without becoming too technical. For this reason, the circuit will be explained as if the IC is a "black box." The various pins are described first, followed by a brief explanation of the external circuitry.

Refer to Figure 4-1 while you read the following information.

Pin 14 (Vcc) — Connects to the positive (+) terminal of a power source, such as a battery. It supplies the DC voltage required by the internal circuitry of the IC. This should be between 4 and 12 volts DC, depending upon the particular brand of IC.

Pin 3, 4, 5, 10, 11, & 12 (ground) — Connects to the negative (−) terminal of a power source and the common line of the circuitry. It provides the return for the internal and external circuitry. NOTE: These pins also serve as a heat sink for the IC. Normally they are tied to a large ground plane on a circuit board to help draw the heat buildup away from the IC.

Pin 13 (output) — Connects to the external circuitry that uses the amplified version of the input.

Pin 8 (noninverting input) — One input to the IC. Signals at the output (pin 13) of the IC will be in phase with the signal applied to this input. This input is normally connected to ground when the inverting input is used.

Pin 7 (inverting input) — One input to the IC. Signals at the output (pin 13) of the IC will be 180 degrees out of phase with (a mirror image of) the signal applied to this input. This input is normally connected to ground when the noninverting input is used.

Pin 1 (bypass) — Normally connects to ground through a capacitor to reduce circuit noise and help stabilize the IC.

Pin 9 (bootstrap) — Connects through a resistor to the supply voltage to set the operating range of the amplifier.

Pins 2 and 6 (gain) — Allow you to set the overall gain of the amplifier. The gain can be set to any number between 20 and 200.

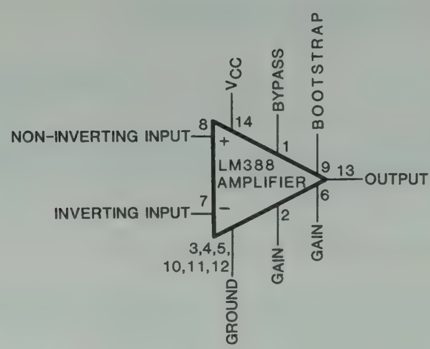


Figure 4-1
(repeat)

Quiz

Refer to Figure 4-1 when you answer the following questions.

1. The Vcc pin of the IC connects to the ____________ terminal of the power source and supplies the voltage required by the ____________ of the IC.

2. The ground pin connects to the ____________ terminal of the power source and provides the ____________ for the internal and external circuitry.

3. The output pin connects to the external circuit that uses ____________ version of the input signal.

4. Pins 2 and 6 allow you to set the overall ____________ of the amplifier.

INPUT CIRCUIT

Refer to Figure 4-2 while you read the following information.

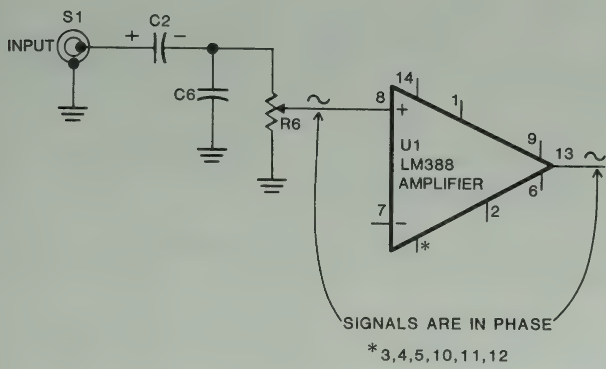


Figure 4-2

Capacitor C2 couples the signal coming from input socket S1 into the IC. Since capacitors allow AC signals to pass but block DC, they effectively isolate any DC in the external circuitry from entering the IC.

Capacitors exhibit reactance, which is similar to resistance, but is frequency sensitive. Capacitive reactance is inversely proportional to frequency. A low-value capacitor will have less resistance at a high frequency and visa versa. Since capacitor C6 in your Amplifier has a fairly small value, it lowers the frequency response of the amplifier and helps stabilize the IC. A proper value capacitor will provide the required frequency response and still add stability.

Control R6 allows you to control the amount of signal that is applied to the input of the IC. In this circuit, it acts as a volume control. Since the total resistance of the control is connected across the input socket, it always presents very little loading on the external input circuit, regardless of the setting of the control.

As described earlier, when the input signal is applied to the non-inverting input of the IC (pin 8), the output signal will look just like the input signal, but will be larger (amplified). There are instances when you may want to use the inverting IC input so that the output signal is a mirror image of the input signal.

Quiz

1. Capacitors allow ____________ signals to pass but block ____________.

2. Capacitors exhibit ____________ which is similar to resistance, but is frequency sensitive.

3. In the circuit in Figure 4-2, control R6 acts as a ____________ control.

4. The inputs to the amplifier IC are referred to as the ____________ input and the ____________ input.

5. When you use the ____________ input of the IC, the output will be a mirror image of the input signal.

POWER SUPPLY CIRCUIT

Refer to Pictorial 4-3 while you read the following information.

Your 1-Watt Audio Amplifier can be powered from either a 9-volt battery or an external power supply. Socket S3 provides an easy way to connect an external supply. When you push a plug into this socket, it automatically disconnects the battery from the circuit. This prevents the battery from discharging through the circuitry when it is not needed.

Diode D1 protects the circuitry in the event the battery, or external supply, is connected with the wrong polarity. If the positive and negative supplies to the IC where interchanged, it would most likely destroy the IC. Diode D1 only conducts when its anode lead is forward biased by a positive voltage. When the battery or power supply is connected incorrectly, diode D1 is reverse biased and protects the IC from damage. Diode D1, therefore, is an inexpensive safety measure that will protect the IC against an improperly connected battery or power supply.

Capacitors C1 and C4 provide filtering and bypassing for the power supply. Capacitor C1 effectively shorts low frequencies to ground and C4 shorts high frequencies to ground. Capacitor C3 also provides bypassing and helps stabilize the circuit.

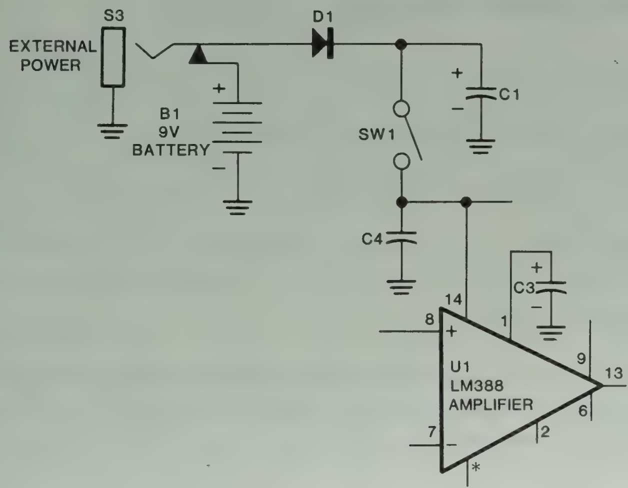


Figure 4-3

Quiz

1. Socket S3 automatically **connects/disconnects** the battery from the circuit when you connect an external power supply. (circle one)

2. Diode D1 protects the circuitry against wrong __________.

3. Capacitors C1 and C4 provide __________ and __________ for the power supply.

4. Capacitor C3 provides bypassing and helps __________ the circuit.

MISCELLANEOUS CIRCUITS

Refer to Figure 4-4 while you read the following information.

Resistors R1 and R3 together with capacitor C5 provide the proper bias for the IC. In most cases, resistors R1 and R3 will be equal in value. Capacitor C5 helps keep the current in R3 constant at all times.

Capacitor C7 and resistor R4 set the gain of the amplifier. Different values allow you to set the gain to anything between 20 and 200 (20 to 200 times the input).

The filter network formed by capacitor C8 and R5 help prevent the circuit from oscillating, and capacitor C9 couples the amplified audio to the load (speaker).

Quiz

Refer to Figure 4-4 when you answer the following questions.

1. Resistors ________ and ________ and capacitor ________ provide the proper bias for the IC.

2. Capacitor C7 and resistor R4 set the ________ of the amplifier.

3. The filter network formed by capacitor ________ and resistor ________ help prevent the circuit from oscillating.

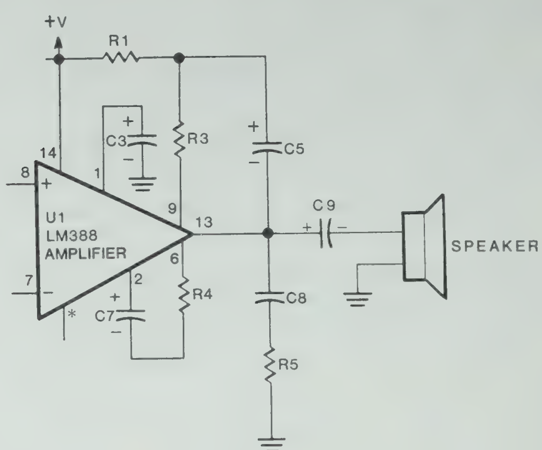


Figure 4-4

LESSON CHECK

1. The Vcc pin of the IC connects to the ____________ terminal of the power source and supplies the voltage required by the ____________ of the IC.

2. The ground pin connects to the ____________ terminal of the power source and provides the ____________ for the internal and external circuitry.

3. The output pin connects to the external circuit that uses ____________ version of the input signal.

4. Capacitors allow ____________ signals to pass but block ____________.

5. Capacitors exhibit ____________, which is similar to resistance but is frequency sensitive.

6. The inputs to the amplifier IC are referred to as the ____________ input and the ____________ input.

7. Diode D1 protects the circuitry against wrong ____________.

8. Capacitor C7 and resistor R4 set the ____________ of the amplifier.

Model SK-105

Fish Caller

The theory behind the Fish Caller is very simple. Dying fish produce a clicking sound that attracts other fish. Your Fish Caller produces the same kind of sound and, by doing so, attracts hungry fish. Since water is an excellent conductor of sounds, it does not take a loud sound to attract fish from a distance.

The heart of your Fish Caller is a type 555 timer IC. This IC can produce oscillations that occur as fast as a fraction of a second to as slow as an hour. The 555 IC has the advantage over a transistor circuit of being inexpensive, small (8-pin IC package), and requiring a minimum of additional external components.

Since the 555 timer IC can be used in a monostable (one-shot) mode and an astable (free-running) mode, it has many applications. Some of these are time-delay generation, sequential timing, linear sweep generation, precision timing, pulse generation, pulse shaping, missing pulse detection, pulse width modulation, and pulse position modulation.

When you complete this lesson, you will be able to:

1. Properly connect a 555 timer IC to generate oscillations.
2. Explain the difference between monostable and astable modes.
3. Change values in the circuit to change the oscillation rate.

CIRCUIT THEORY

The object of this lesson is to show you how to use a 555 timer IC without becoming too technical. For this reason, the circuit will be explained as if the IC is a "black box." The various pins are described first, followed by a brief explanation of the external circuitry.

Refer to Figure 5-1 while you read the following information.

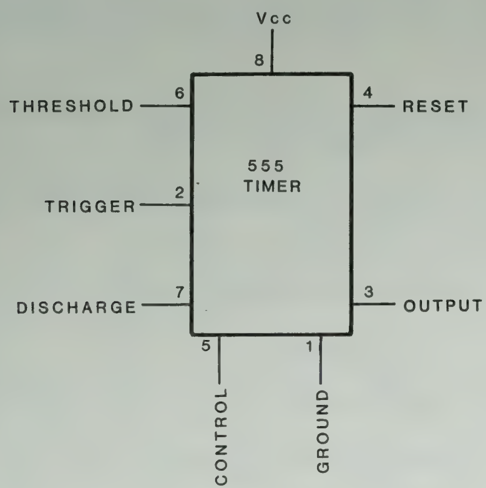


Figure 5-1

Pin 8 (Vcc) — Connects to the positive (+) terminal of a power source, such as a battery. It supplies the DC voltage required by the internal circuitry of the IC. This should be between 4-1/2 and approximately 18 volts DC, depending upon the particular brand of IC.

Pin 1 (ground) — Connects to the negative (−) terminal of a power source and the common line of the circuitry. It provides the return for the internal and external circuitry.

Pin 3 (output) — Connects to an external circuit that uses the oscillations produced by the timer. In the case of your Fish Caller, it connects to a transducer so that the oscillations are audible.

Pin 5 (control) — Provides access to a reference point inside the IC. Allows you to modify the timing period or reset one of the internal circuits. When it is not used, such as in your Fish Caller, it should be connected to ground through a capacitor. This capacitor helps reduce circuit noise.

Pin 2 (trigger) — Connects to an external timing circuit to start the timing operation.

Pin 6 (threshold) — Connects to an external timing circuit to stop the timing operation.

Pin 4 (reset) — Allows you to reset the timing operation. This connection allows you to override the timing operation.

Pin 7 (discharge) — Connects to the external timing circuit to discharge the capacitor in that circuit.

Refer to Figure 5-2 while you read the following information.

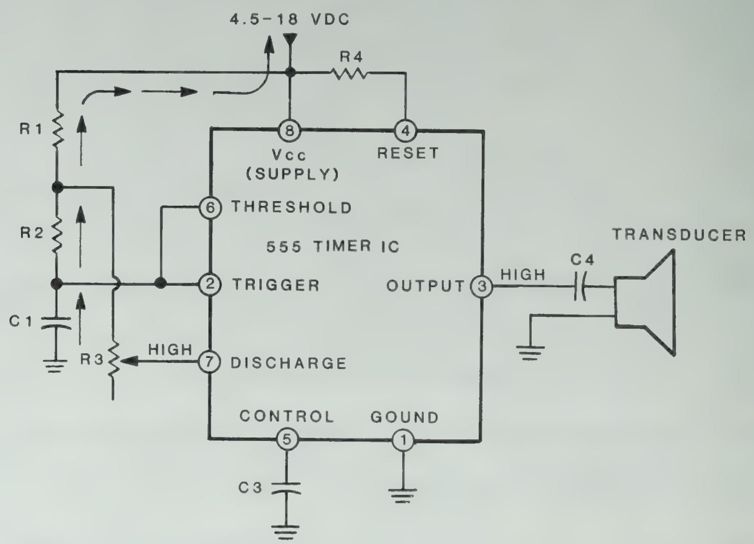


Figure 5-2

Resistors R1 and R2, together with capacitor C1, are connected across the power source to form a voltage divider. As capacitor C1 charges toward the supply voltage, it will reach the trigger point of the IC at pin 2. The rate at which the capacitor charges is directly related to the values of the components used in the divider.

Prior to the time that the IC triggers, output pin 3 and discharge pin 7 are high. As soon as the IC triggers, the output pin and the discharge pin go low (see Figure 5-3). This acts as a short across capacitor C1 and forces it to discharge through resistors R2, control R3, and the IC. The rate of discharge depends upon the values of R2, R3, and C1.

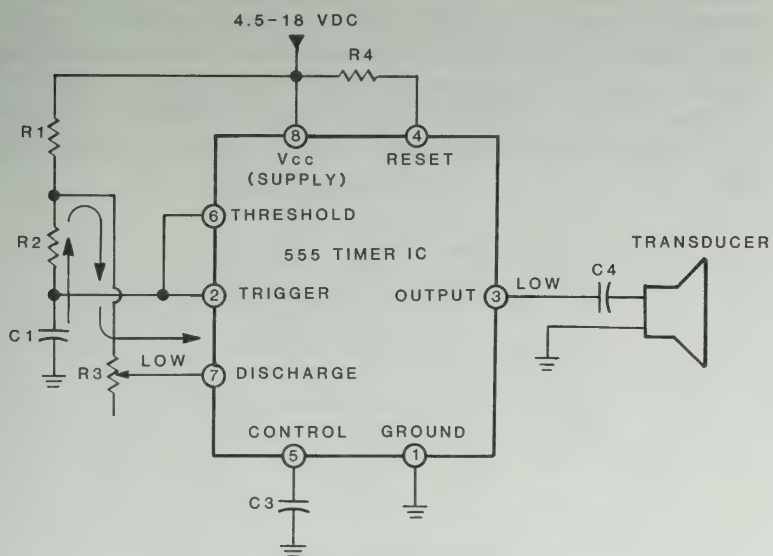


Figure 5-3

When the capacitor discharges to the threshold point of the IC at pin 6, outputpin 3 and discharge pin 7 will again go high. The process will then repeat until you remove power from the circuit. With the output of the IC continually alternating between high and low, you have essentially an oscillator whose frequency depends upon the value of R1, R2, R3, and C1. These impulses then pass through capacitor C4 to the transducer, which produces a clicking sound. Since the oscillator is free running, it is operating in the astable mode.

Although a fixed-value resistor could be used at R3, the control allows you to vary the frequency of oscillation over a limited range. You could change the frequency over a wider range by changing the values of resistors R1 and R2 and capacitor C1. The nomogram in Figure 5-4 shows the approximate values of the components needed to make the timer operate at different frequencies. NOTE: The resistances shown are for the sum of the value of R1 plus two times the value of R2. To construct an oscillator that has a frequency of 1000 Hz, for example, you could use 33 kΩ resistors at R1 and R2 and use a .01 μF capacitor at C1.

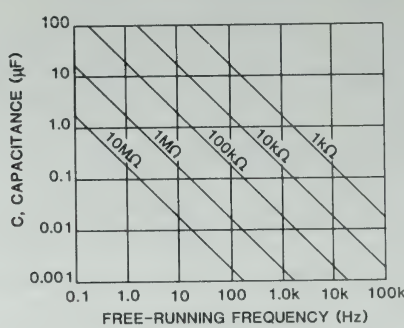


Figure 5-4

The IC can be connected to operate in the monostable (one shot) mode as shown in Figure 5-5. The circuit is somewhat similar to the astable circuit but since it triggers only once, the circuit is simpler. When you close the switch, the timer waits a period of time determined by the values of R1 and C1, and then switches the output from low to high. The monostable mode could be used to trigger a device at a specific time after the IC has been actuated. One place it could be used is in an automobile burglar alarm. It would allow you time to exit the vehicle after the alarm system has been turned on and before the alarm circuits are actually armed.

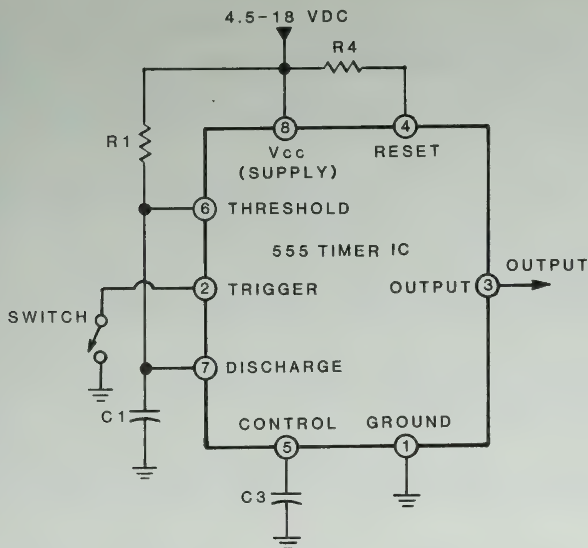


Figure 5-5

LESSON CHECK

Refer back to Figure 5-1 for the following questions.

1. The Vcc pin of the IC connects to the ______________ terminal of the power source and supplies the voltage required by the ______________ ___________ of the IC.

2. The ground pin connects to the ______________ terminal of the power source and provides the ______________ for the internal and external circuitry.

3. The output pin connects to an external circuit that uses the ______________ produced by the timer.

Refer back to Figure 5-2 for the following questions.

4. As capacitor C1 charges toward the supply voltage, it will reach the ______________ point of the IC at pin 2.

5. The rate at which capacitor C1 charges is directly related to the values of ___________, ___________, and ___________.

6. The rate of discharge depends upon the values of ___________, ___________, and ___________.

7. With the output of the IC continuously alternating between high and low, you essentially have an ______________.

8. Control R3 allows you to ______________ the frequency of oscillation.

9. The timer in you Fish Caller operates in the **monostable/astable** mode. (circle one)

10. Another name for a monostable mode of operation is ______________.

Model SK-106

FM Wireless Microphone

Your FM Wireless Microphone is a small FM transmitter built into a microphone-sized package. It allows you to transmit to any standard FM receiver within its range (up to about 50′).

When you complete this lesson, you will:

1. Be able to draw the symbols of a PNP and an NPN transistor.

2. Be able to properly connect both PNP and NPN transistors in a circuit.

3. Understand the operation of a complementary transistor amplifier stage.

4. Understand how an FM oscillator works.

CIRCUIT THEORY

INPUT CIRCUIT

Refer to Figure 6-1 while you read the following information.

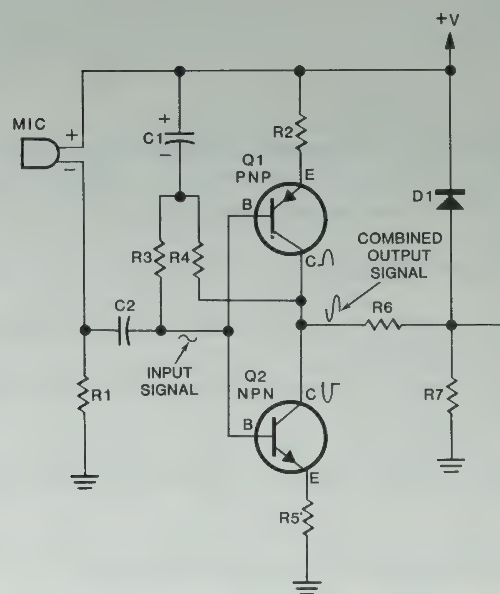


Figure 6-1

The input circuit consists of the microphone element (MIC), transistors Q1 and Q2, and the associated resistors and capacitors. Transistors Q1 and Q2 form what is known as a "complementary amplifier" due to the way these different-type transistors are connected in the circuit. You can tell from the symbols that Q1 is a PNP transistor (emitter arrow points in) and Q2 is an NPN transistor (emitter arrow points out).

Before a PNP transistor can conduct, it must have a positive voltage on its emitter, a negative voltage on its collector, and a slightly negative voltage on its base (with respect to the emitter). Conversely, for an NPN transistor to conduct, it must have a positive voltage on its collector, a negative voltage on its emitter, and a slightly positive voltage on its base (with respect to the emitter). Since the transistors are opposite in the way they are biased, they are complementary.

When you speak into the microphone, the sound (audio) signal passes through capacitor C2 to the bases of transistors Q1 and Q2. Since the microphone requires a DC voltage to operate (as indicated by the + and − marks), capacitor C2 passes the audio but blocks the DC from interfering with the biasing of the transistors.

Due to the way the transistors are biased, transistor Q2 only conducts during the positive half cycle of the audio and transistor Q1 only conducts during the negative half cycle. Since the signal at the collector of a transistor is inverted from the input signal, transistor Q2 produces the negative half of the signal and transistor Q1 produces the positive half. The combination of these two half signals produce a complete waveform that is amplified, but inverted, from the input signal.

Resistor R1 biases the microphone, while resistors R3 and R4 bias the transistors for the proper operation. The way that resistors R3 and R4 are connected into the circuit is referred to as "self-biasing." Resistors R2 and R5 provide current limiting and help balance the transistors, to make up for varying gains. Capacitor C1 bypasses the audio that is present at the junction of these two resistors to the supply line, which acts as an audio ground (or common line).

Resistors R6 and R7 and diode D1 make up the load for transistors Q1 and Q2. In addition, diode D1 keeps the amplified audio from becoming too large and overdriving the oscillator, which you will learn about next.

Quiz

1. Draw the symbol of an NPN transistor.

2. Draw the symbol of a PNP transistor.

3. For a PNP transistor to conduct, it must have a ____________ voltage on its emitter, a ____________ voltage on its collector, and a slightly ____________ voltage on its base.

4. For an NPN transistor to conduct, it must have a ____________ voltage on its emitter, a voltage on its collector, and a slightly ____________ voltage on its base.

Refer to Figure 6-1 when you answer the following questions.

5. Capacitor C2 passes the ____________ but blocks the DC from interfering with the biasing of the transistors.

6. The signal that is present at the junction of the collectors is amplified, but ____________ from the input signal.

FM OSCILLATOR CIRCUIT

Refer to Figure 6-2 while you read the following information.

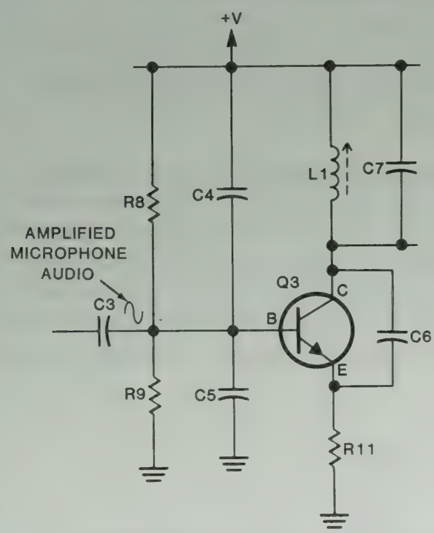


Figure 6-2

Now that you have learned how to amplify the audio coming from the microphone, you need to learn how to transmit the audio over the air. The purpose of this oscillator circuit is to generate radio frequency (RF) energy. This RF energy can then be modulated (have audio added to it) so that you can transmit the audio over the air.

Transistor Q3 forms the heart of the oscillator circuit. Coil L1 and capacitor C7 form a "tank" circuit that sets the frequency of oscillation. You may recall from one of the other lessons that you could use a timer IC to produce oscillations. Here, however, you must use a tank circuit because the frequency generated is more than 800 times higher. Coil L1 is adjustable so you can set the frequency over a particular range (in this case, 88 to 108 MHz). In some similar circuits, you may find that the capacitor is adjustable instead of the coil. Capacitor C6 provides some feedback from the emitter to the collector to help keep the oscillator running.

Resistors R8 and R9 together with capacitors C4 and C5 provide the proper operating bias for the transistor, while resistor R11 provides current limiting.

Oscillator modulation falls into two basic groups: AM (amplitude modulation) and FM (frequency modulation). Since the modulation (audio) passes through capacitor C3 and is applied to the base of Q3, the frequency of oscillation will vary at the modulation rate. This frequency variation is commonly referred to as "frequency modulation."

In an AM oscillator, the frequency stays the same but the amplitude (size) of the signal varies with the amount of modulation. In summary, an FM transmitter always puts out the same amount of RF (radio frequency) but the frequency varies with the modulation. The frequency of an AM transmitter, however, stays the same, but the amount of power radiated varies with the amount of modulation (AM and FM transmitters always radiate some RF, called a "carrier," even with no modulation).

Quiz

1. The purpose of the oscillator is to generate ____________ energy.

2. The audio that is added to an RF signal is referred to as ____________.

Refer to Figure 6-2 when you answer the following questions.

3. Coil L1 and capacitor C7 form a ____________ circuit that sets the frequency of oscillation.

4. The frequency produced by this oscillator is much **higher/lower** than you could obtain from a timer IC.

5. ____________ modulation means that the oscillator changes frequency at the modulation rate.

OUTPUT CIRCUIT

Refer to Figure 6-3 while you read the following information.

Capacitor C8 couples the modulated RF signal into a tuned circuit formed by coil L2, capacitor C11, and resistor R12. This circuit is tuned to the center of the FM broadcast band and is not adjustable. Resistor R12 swamps (broadens) the operating range of the circuit so it covers the entire band.

The resultant signal is then coupled through capacitor C9 to the antenna.

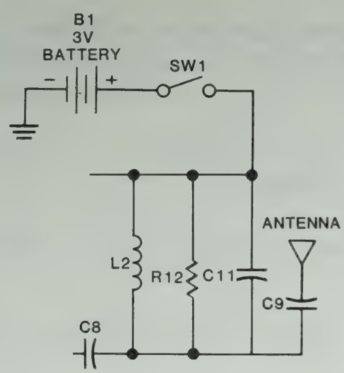


Figure 6-3

LESSON CHECK

1. Draw the symbol of an NPN transistor.

2. For a PNP transistor to conduct, it must have a ____________ voltage on its emitter, a ____________ voltage on its collector, and a slightly ____________ voltage on its base.

3. For an NPN transistor to conduct, it must have a ____________ voltage on its emitter, a ____________ voltage on its collector, and a slightly ____________ voltage on its base.

4. The purpose of the oscillator is to generate ____________ ____________ energy.

5. The audio that is added to an RF signal is referred to as ____________.

Refer to Figure 6-4 when you answer the following questions.

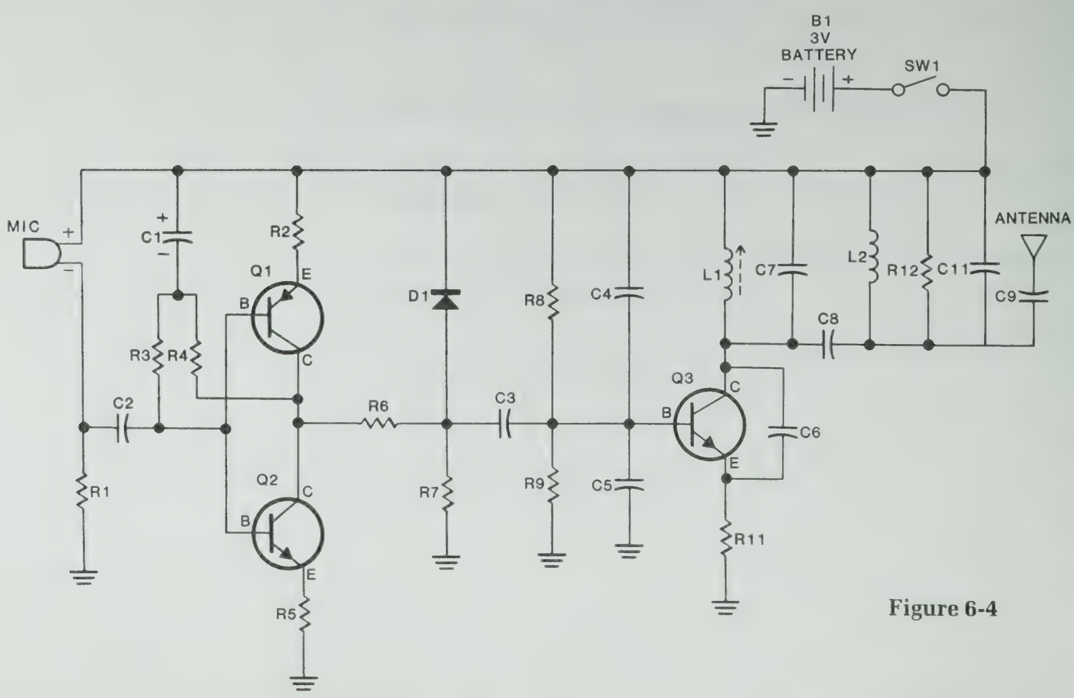


Figure 6-4

6. Capacitor C2 passes the ____________ but blocks the DC from interfering with the biasing of the transistors.

7. The signal that is present at the junction of the collectors is amplified, but ____________ from the input signal.

8. Coil L1 and capacitor C7 form a ____________ circuit that sets the frequency of oscillation.

9. The frequency produced by this oscillator is much **higher/lower** than you could obtain from a timer IC.

10. ____________ modulation means that the oscillator changes frequency at the modulation rate.

Model SK-107

Stereo Synthesizer

The type TBA-3810 integrated circuit that is used in this kit is capable of three modes of operation: spatial, stereo, and pseudo stereo. The spatial mode takes a stereo (two-channel) input and adds enhancement to make it sound more dynamic, the stereo mode is straight-through operation, and the pseudo-stereo mode takes a mono (monaural, or single-channel) input and converts it into two different channels.

Your Model SK-107 Stereo Synthesizer operates in the pseudo- stereo mode and converts a mono signal into two channels that resemble stereo. Although the Synthesizer does not produce true stereo, it does produce a better sound than mono and can be used with an AM radio, a television set, etc.

When you complete this lesson, you will:

1. Understand the purpose of a low-pass filter.

2. Understand the purpose of a high-pass filter.

3. Understand the purpose of a bandpass filter.

CIRCUIT THEORY

The object of this lesson is to show you how to use a TBA-3810 IC without becoming too technical. For this reason, the circuit will be explained as if the IC were a "black box." The various pins are described first, followed by a brief explanation of the external circuitry.

Refer to Figure 7-1 while you read the following information.

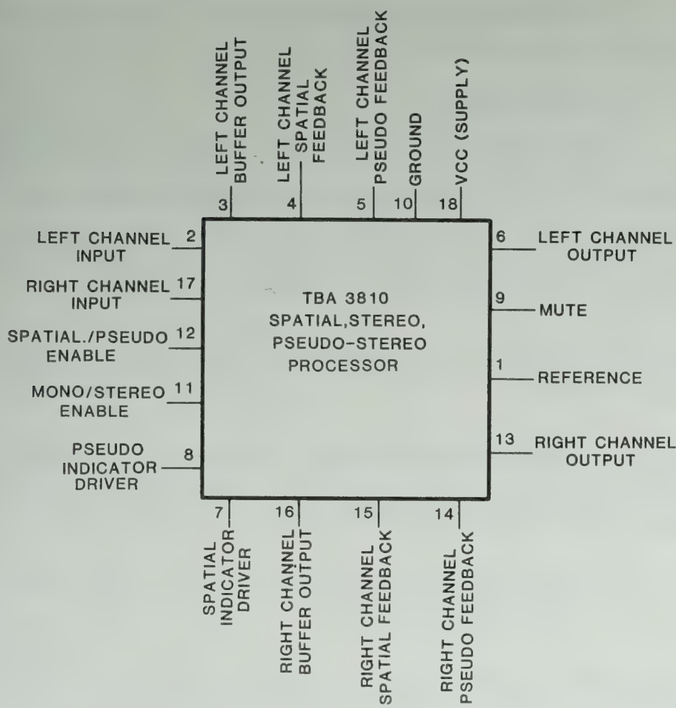


Figure 7-1

Pin 1 — Reference line for the IC. This pin is normally connected to ground through a capacitor.

Pin 2 — Left channel input to the IC.

Pin 3 — Left channel buffer output from the IC.

Pin 4 — Left channel spatial feedback input. This pin is only used in the spatial mode.

Pin 5 — Left channel pseudo feedback input. This pin is used only in the pseudo-stereo mode.

Pin 6 — Left channel output.

Pin 7 — Spatial indicator driver. This pin is used with an indicator lamp to show you when the spatial mode has been selected.

Pin 8 — Pseudo indicator driver. This pin is used with an indicator lamp to show you when the pseudo mode has been selected.

Pin 9 — Mute connection. This pin is normally connected to ground through a capacitor.

Pin 10 — Connects to the negative (−) terminal of the power source and the common line of the circuitry. It provides the return for the internal and external circuitry.

Pin 11 — Mono/stereo enable. Connect to 2 to 18-volts DC to select stereo; 0 to 0.8 volts to select mono.

Pin 12 — Spatial/pseudo enable. Connect to 2 to 18-volts DC to select the spatial mode; 0 to 0.8 volts to select the pseudo mode.

Pin 13 — Right channel output from the IC.

Pin 14 — Right channel pseudo feedback input. This pin is used only in the pseudo-stereo mode.

Pin 15 — Right channel spatial feedback input. This pin is only used in the spatial mode.

Pin 16 — Right channel buffer output from the IC.

Pin 17 — Right channel input to the IC.

Pin 18 — Connects to the positive (+) terminal of the power source and supplies the DC voltage required by the internal circuitry of the IC.

Quiz

Refer to Figure 7-1 when you answer the following questions.

1. The Vcc pin of the IC connects to the ______________ terminal of the power source and supplies the voltage required by the ______________ ______________ of the IC.

2. The ground pin connects to the ______________ terminal of the power source and provides the ______________ for the internal and external circuitry.

3. Pin 2 is the ______________ channel input to the IC.

4. Pin 17 is the ______________ channel input to the IC.

5. Pin 6 is the ______________ channel output of the IC.

6. Pin 13 is the ______________ channel output of the IC.

The following paragraphs explain how the IC operates in the pseudo-stereo mode.

INPUT CIRCUIT

Refer to Figure 7-2 while you read the following information.

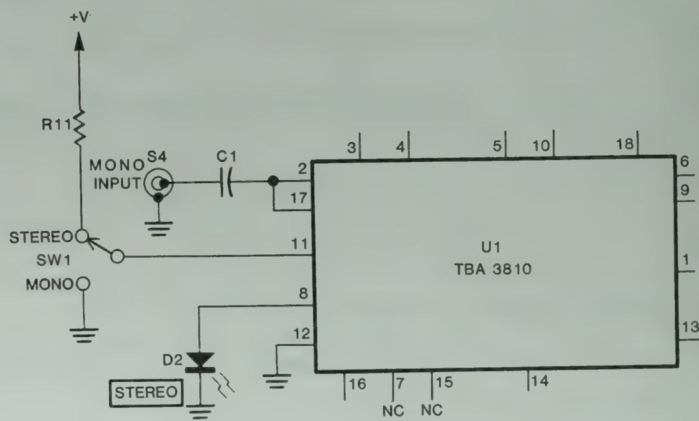


Figure 7-2

In the pseudo-stereo mode, the IC compares the audio at the left-channel input to the audio at the right-channel input and then mathematically produces differing signals at the left and right-channel outputs. Pin 12 of the IC is connected to ground to select this mode.

When pin 11 is high (2 to 18-volts DC), the IC operates in the stereo mode and will produce different output signals. When pin 11 is low (0 to 0.8 volts DC), the IC operates in the mono mode and will produce identical output signals at the two outputs. Pin 8 is connected through LED (light-emitting diode) D2 to indicate when you have selected the stereo mode.

Capacitor C1 couples the audio coming from Input socket S4 into the IC. Resistor R11 is a pull-up resistor that applies the supply voltage to pin 11 in the stereo mode.

Since the circuit operates in the pseudo-stereo mode, the left-channel input (pin 2) and right-channel input (pin 17) are tied together. This common connection applies the mono signal to both inputs of the IC. In the other modes, these inputs would not be connected together.

Quiz

Refer to Figure 7-2 when you answer the following questions.

1. Your Stereo Synthesizer operates in the ____________ stereo mode.

2. The IC compares the audio at the left-channel input to the audio at the right-channel input and then ____________ produces ____________ signals at the left and right-channel outputs.

3. LED D2 lights to indicate that you have selected the **mono/stereo** mode. (circle one)

4. Switch SW1 applies a **high/low** to IC pin 11 to select the stereo mode. (circle one)

LEFT CHANNEL CIRCUIT

Refer to Figure 7-3 while you read the following information.

The input signal for the left channel enters the IC at pin 2, is buffered, and exits at pin 3. The signal then passes through capacitor C2 and resistor R1 before it re-enters the IC at pin 5, where it is buffered again and exits the IC at pin 6. Capacitor C10 couples the left channel signal to Left Output socket S2. Resistor R2 provides feedback and sets the gain of the additional buffer stage. The output of the IC at pin 6 is essentially an unchanged version of the signal applied to the input at pin 2.

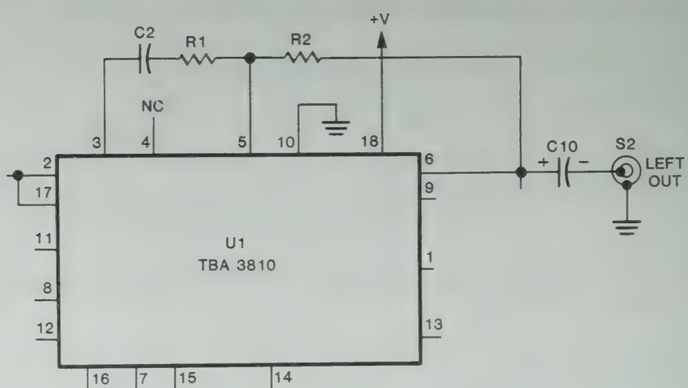


Figure 7-3

RIGHT CHANNEL CIRCUIT

Refer to Figure 7-4 while you read the following information.

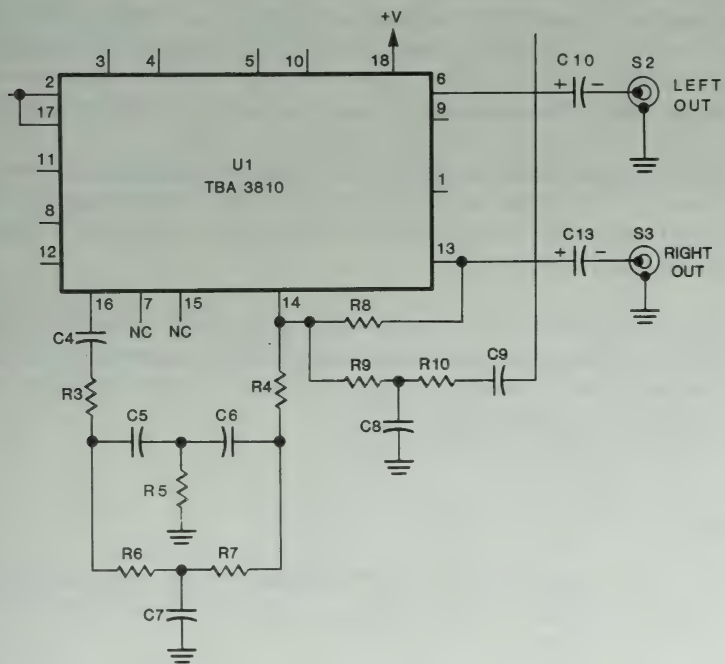


Figure 7-4

The input signal for the right channel enters the IC at pin 17, is buffered, and exits at pin 16. Capacitor C4 and resistor R3 couple the signal to a double-T filter formed by C5, C6, C7, R5, R6, and R7. Capacitors C5 and C6 and resistor R5 form a high-pass filter that passes only the high frequencies of the input signal. Conversely, resistors R6 and R7 and capacitor C7 form a low-pass filter that passes only the low frequencies of the input signal. The result of these two filters is similar to the input signal, except that the middle frequencies are missing. The output of these filters passes through resistor R4 to IC pin 14.

A portion of the left-channel output passes through capacitor C9 to the bandpass filter formed by resistors R9 and R10 and capacitor C8. This filter passes only the mid frequencies and applies them to IC pin 14. Since high frequencies, low frequencies, and mid frequencies are all applied to pin 14, it appears as though the signal at this pin is very similar to the input signal. The signals coming from the double-T filter and the bandpass filter, however, have different amplitudes and phases. Pin 14, therefore, acts as a summing point for the two signals.

The difference signal enters the IC at pin 14, where it is buffered and exits at pin 13. Capacitor C13 couples the right channel signal to Right Output socket S3. Resistor R8 provides feedback and sets the gain of the additional buffer stage.

The signal at the right channel output sounds different than the signal at the left channel output because the middle frequencies are out-of-phase with the higher and lower frequencies. This results in something that sounds like stereo.

Quiz

1. The output of the IC at the **Left/Right** Output socket is essentially an unchanged version of the signal applied to the input at pin 2. (circle one)

Refer to Figure 7-4 when you answer the following questions.

2. Capacitors C5, C6, and C7, and resistors R5, R6, and R7 form a ____________ filter.

3. Capacitors C5 and C6 and resistor R5 form a ____________-pass filter that passes only the ____________ frequencies of the input signal.

4. Resistors R6 and R7, and capacitor C7 form a ____________-pass filter that passes only the ____________ frequencies of the input signal.

5. Resistors R9 and R10 and capacitor C8 form a ____________ filter that passes only the mid frequencies and applies them to IC pin 14.

6. The signals coming from the double-T filter and the bandpass filter have different ____________ and ____________.

7. The signal at the right channel output sounds different than the signal at the left channel output because the middle frequencies are **out-of-phase/in-phase** with the high and low frequencies. (circle one)

MISCELLANEOUS CIRCUITRY

Refer to Figure 7-5 while you read the following information.

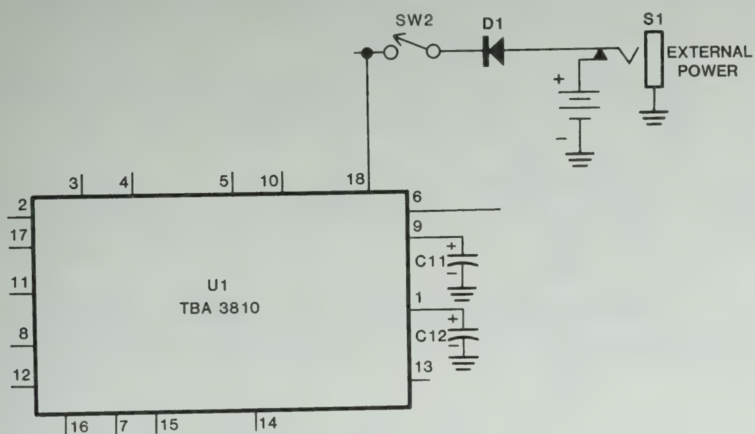


Figure 7-5

Capacitor C11 provides filtering for the mute circuitry inside the IC, and C12 acts as a reference filter for the IC.

Your Stereo Synthesizer can be powered from either a 9-volt battery or an external power supply. Socket S1 provides an easy way to connect an external supply. When you push a plug into this socket, it automatically disconnects the battery from the circuit. This prevents the battery from discharging through the circuitry when it is not needed.

Diode D1 protects the circuitry in the event the battery, or external supply, is connected with the wrong polarity. If the positive and negative supplies to the IC were interchanged, it would most likely destroy the IC. Diode D1 is an inexpensive safety measure that will protect the IC against an improperly connected battery or power supply.

LESSON CHECK

Refer to Figure 7-6 when you answer the following questions.

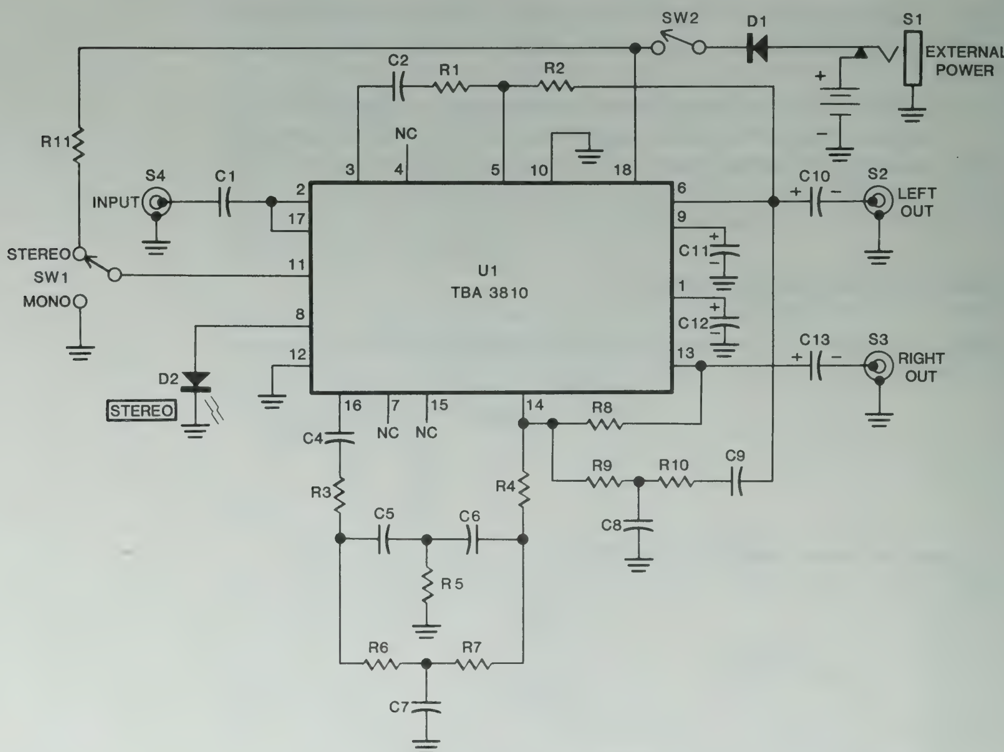


Figure 7-6

1. The Vcc pin of the IC connects to the ____________ terminal of the power source and supplies the voltage required by the ____________ ____________ of the IC.

2. The ground pin connects to the ____________ terminal of the power source and provides the ____________ for the internal and external circuitry.

3. Your Stereo Synthesizer operates in the ____________ stereo mode.

4. The IC compares the audio at the left-channel input to the audio at the right-channel input and then ____________ produces ____________ signals at the left and right-channel outputs.

5. The output of the IC at the **Left/Right** Output socket is essentially an unchanged version of the signal applied to the input at pin 2. (circle one)

6. Capacitors C5, C6, and C7, and resistors R5, R6, and R7 form a ____________ filter.

7. Capacitors C5 and C6 and resistor R5 form a ____________-pass filter that passes only the ____________ frequencies of the input signal.

8. Resistors R6 and R7, and capacitor C7 form a ____________-pass filter that passes only the ____________ frequencies of the input signal.

9. Resistors R9 and R10 and capacitor C8 form a ____________ filter that passes only the mid frequencies and applies them to IC pin 14.

10. The signals coming from the double-T filter and the bandpass filter have different ____________ and ____________.

11. The signal at the right channel output sounds different than the signal at the left channel output because the middle frequencies are **out-of-phase/in-phase** with the high and low frequencies. (circle one)

Model SK-108

Wired Intercom

The heart of your Wired Intercom is a type LM388 integrated circuit amplifier. The LM388 has the advantage over a transistor circuit of being inexpensive, small (14-pin IC package), and requiring only a few external components.

Some of the applications where you might find this type of amplifier are in AM-FM radios, portable tape players, intercoms, and television sound systems.

When you complete this lesson, you will:

1. Be able to properly connect an LM388 IC in a circuit.

2. Be able to change values in the circuit to change the overall available gain.

3. Understand how to use a transformer to match different impedances.

4. Describe how a speaker can be used as a microphone.

CIRCUIT THEORY

The object of this lesson is to show you how to use an LM388 amplifier IC without becoming too technical. For this reason, the circuit will be explained as if the IC is a "black box." The various pins are described first, followed by a brief explanation of the external circuitry.

Refer to Figure 8-1 while you read the following information.

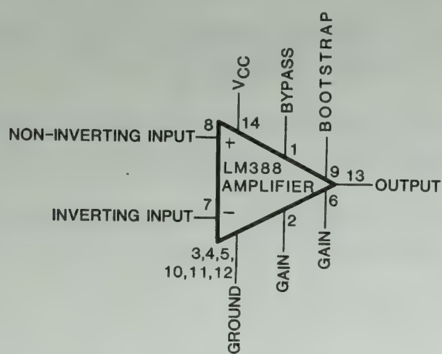


Figure 8-1

Pin 14 (Vcc) — Connects to the positive (+) terminal of a power source, such as a battery. It supplies the DC voltage required by the internal circuitry of the IC. This should be between 4 and 12 volts DC, depending upon the particular brand of IC.

Pin 3, 4, 5, 10, 11, & 12 (ground) — Connects to the negative (−) terminal of a power source and the common line of the circuitry. It provides the return for the internal and external circuitry. NOTE: These pins also serve as a heat sink for the IC. Normally they are tied to a large ground plane on a circuit board to help draw heat buildup away from the IC.

Pin 13 (output) — Connects to the external circuitry that uses the amplified version of the input.

Pin 8 (noninverting input) — One input to the IC. Signals at the output(pin 13) of the IC will be in phase with the signal applied to this input. This input is normally connected to ground when the inverting input is used.

Pin 7 (inverting input) — One input to the IC. Signals at the output (pin 13) of the IC will be 180 degrees out of phase with (a mirror image of) the signal applied to this input. This input is normally connected to ground when the noninverting input is used.

Pin 1 (bypass) — Normally connects to ground through a capacitor to reduce circuit noise and help stabilize the IC.

Pin 9 (bootstrap) — Connects through a resistor to the supply voltage to set the operating range of the amplifier.

Pins 2 and 6 (gain) — Allow you to set the overall gain of the amplifier. The gain can be set to any number between 20 and 200.

Quiz

Refer to Figure 8-1 when you answer the following questions.

1. The Vcc pin of the IC connects to the ____________ terminal of the power source and supplies the voltage required by the ____________ ____________ of the IC.

2. The ground pin connects to the ____________ terminal of the power source and provides the ____________ for the internal and external circuitry.

3. The output pin connects to the external circuit that uses the ____________ version of the input signal.

4. Pins 2 and 6 allow you to set the overall ____________ of the amplifier.

TALK/LISTEN CIRCUIT

Refer to Figure 8-2 while you read the following information.

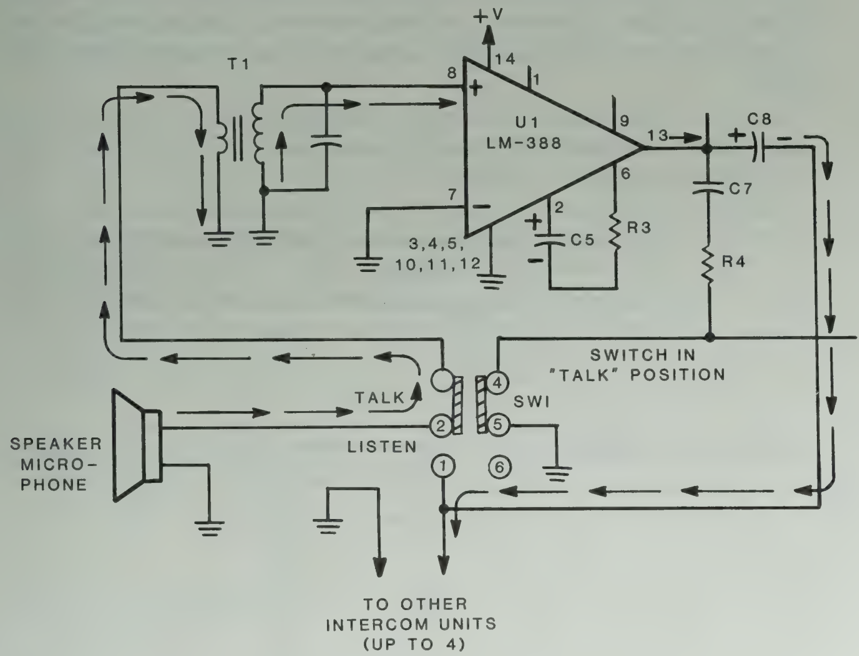


Figure 8-2

When you hold the slide switch in the "Talk" position, the speaker is connected to one winding of transformer T1. Since the other winding of the transformer is connected to the input of integrated circuit amplifier U1, the speaker acts as a microphone. Any sound present at the speaker/microphone is coupled through T1 to the input of the amplifier IC.

T1 is referred to as a step-up transformer because it transforms the low impedance at the primary (input) winding to a high impedance at the secondary (output) winding. The number of turns in the windings is directly proportional to the impedance. Impedance transformation is necessary to match the low speaker impedance to the high impedance at the input (pin 8) of integrated circuit U1. All coils have impedance, which is similar to resistance, but is frequency sensitive. Since speakers and transformers contain one or more coils, they are impedance devices.

Integrated circuit U1 amplifies the microphone audio and couples it through capacitor C8 to the other intercom units. The audio (sound) signal is applied to the noninverting input of the IC (pin 8). This means that the output signal will look just like the input signal, but will be larger (amplified). There are instances when you may want to use the other IC input so that the output signal is a mirror image of the input signal.

Capacitor C1 is connected across the secondary winding of T1 to reduce the frequency response and help stabilize the IC.

When the slide switch is in the "Listen" position, as shown in Figure 8-3, the amplifier circuits are disabled. Audio that has been amplified by one of the other Intercom units (as described above in "Talk Circuit") passes directly to the speaker through the one side of switch SW1.

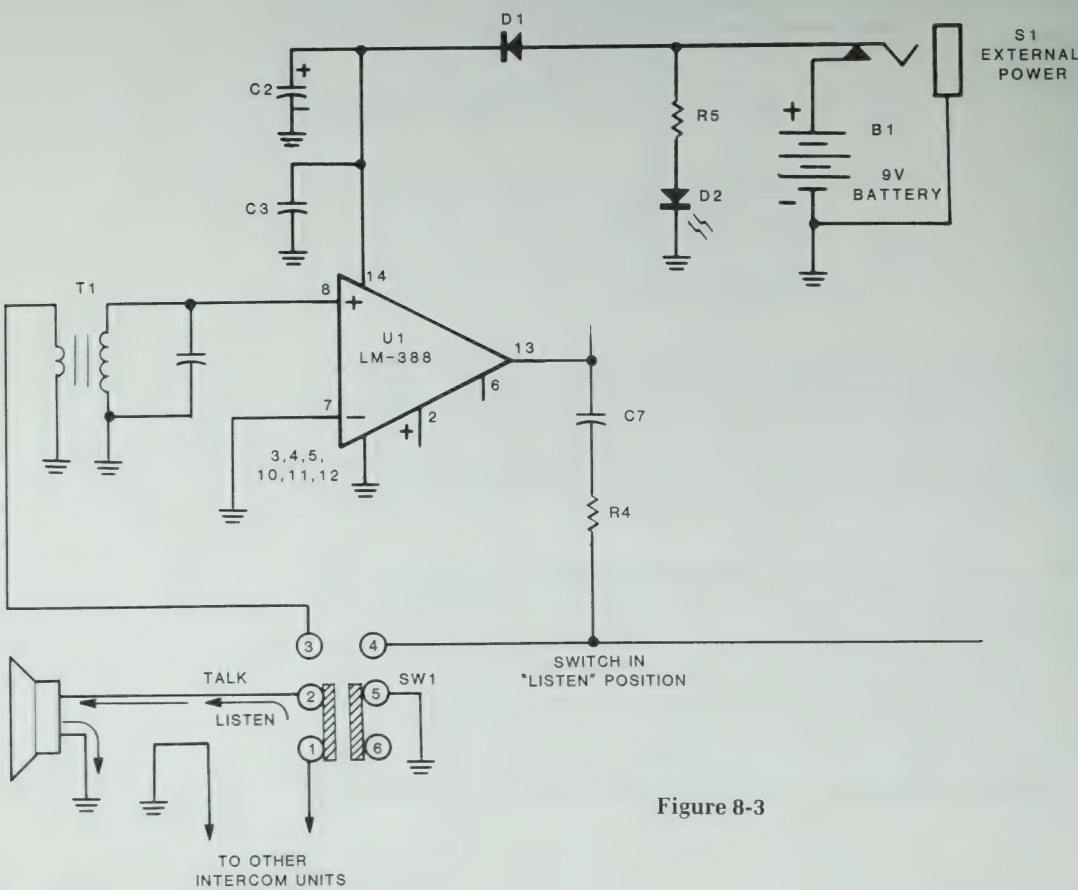


Figure 8-3

Quiz

Refer to Figure 8-2 when you answer the following questions.

1. When you hold the slide switch of your Intercom in the Talk position, the speaker acts as a ____________.

2. T1 is referred to as a **step-up/step down** transformer because it transforms a low impedance to a high impedance. (circle one)

3. The number of turns in the windings of a transformer are **indirectly/directly** proportional to impedance. (circle one)

4. Speakers and transformers are ____________ devices.

5. When you use the ____________ input of the IC, the output will be a mirror image of the input signal.

6. When the slide switch is in the Listen position, audio that has been amplified by another Intercom unit passes directly to the ____________ through the switch.

POWER SUPPLY CIRCUIT

Refer to Figure 8-3 while you read the following information.

Your Intercom can be powered from either a 9-volt battery or an external power supply. Socket S1 provides an easy way to connect an external supply. When you push a plug into this socket, it automatically disconnects the battery from the circuit. This prevents the battery from discharging through the circuitry when it is not needed.

Diode D1 protects the circuitry in the event the battery, or external supply, is connected with the wrong polarity. If the positive and negative supplies to the IC where interchanged, it would most likely destroy the IC. Diode D1 only conducts when its anode lead is forward biased by a positive voltage. When the battery or power supply is connected incorrectly, diode D1 is reverse biased and protects the IC from damage. Diode D1, therefore, is an inexpensive safety measure that will protect the IC against an improperly connected battery or power supply.

LED (light-emitting diode) D2 lights when the Intercom is in the Talk mode. Resistor R5 limits the current that is supplied to the LED.

Capacitors C2 and C3 provide filtering and bypassing for the power supply. Capacitor C2 effectively shorts low frequencies to ground and C3 shorts high frequencies to ground. Capacitor C4 also provides bypassing and helps stabilize the circuit.

Quiz

Refer to Figure 8-3 when you answer the following questions.

1. Socket S1 automatically **connects/disconnects** the battery from the circuit when you connect an external power supply. (circle one).

2. Diode D1 protects the circuitry against wrong ______________.

3. Capacitors C2 and C3 provide ______________ and ______________ for the power supply.

4. Capacitor C4 provides bypassing and helps ______________ the circuit.

MISCELLANEOUS CIRCUITS

Refer to Figure 8-4 while you read the following information.

Resistors R1 and R2 together with capacitor C6 provide the proper bias for the IC. In most cases, resistors R1 and R2 will be equal in value. Capacitor C6 helps keep the current in R3 constant at all times.

Capacitor C5 and resistor R3 set the gain of the amplifier. Different values allow you to set the gain to anything between 20 and 200 (20 to 200 times the input).

The filter network formed by capacitor C7 and resistor R4 help prevent the circuit from oscillating.

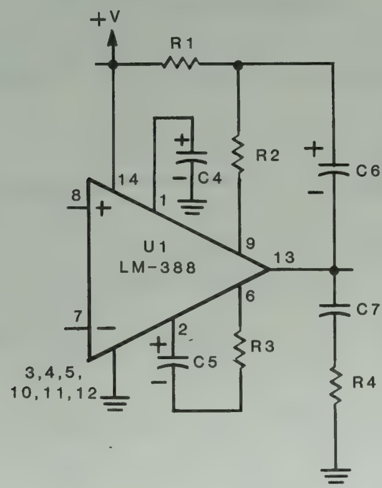


Figure 8-4

Quiz

Refer to Figure 8-4 while you answer the following questions.

1. Resistors __________ and __________ and capacitor __________ provide proper bias for the IC.

2. Capacitor C5 and resistor R3 set the _____________ of the amplifier.

3. The filter network formed by capacitor __________ and resistor __________ help prevent the circuit from oscillating.

LESSON CHECK

Refer to Figure 8-5 when you answer the following questions.

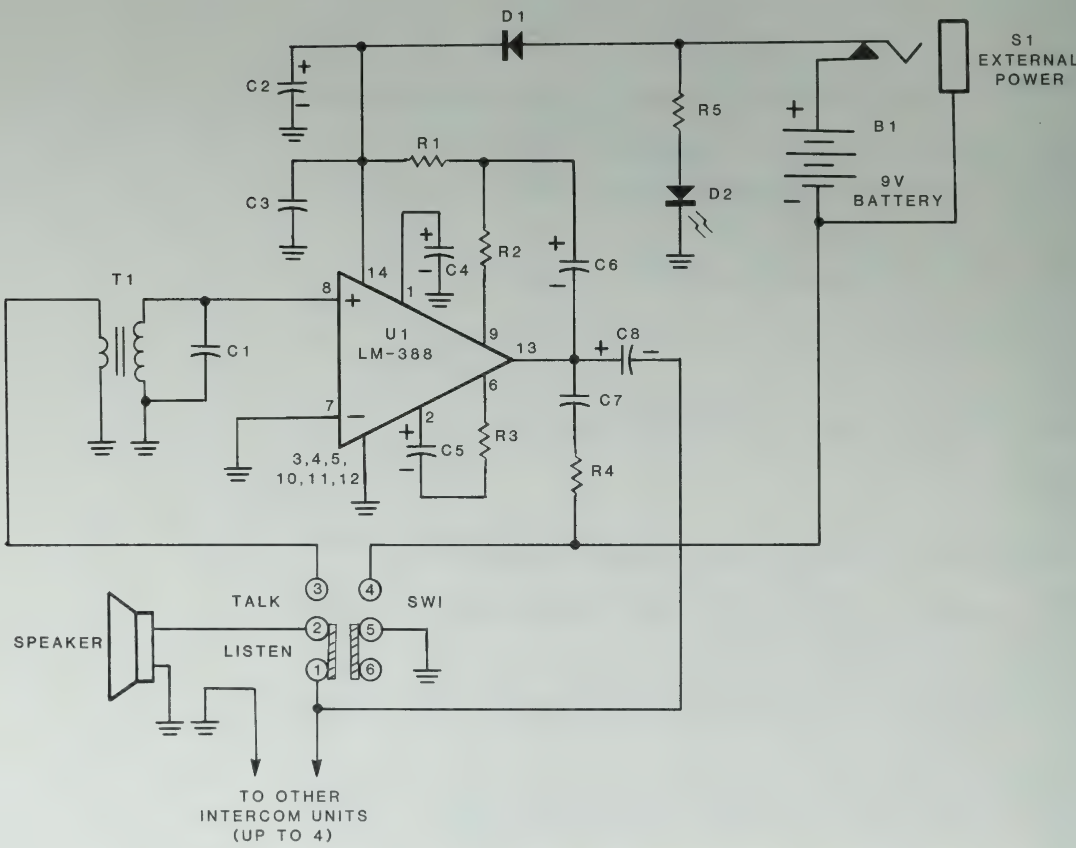


Figure 8-5

1. The Vcc pin of the IC connects to the ____________ terminal of the power source and supplies the voltage required by the ____________ of the IC.

2. The ground pin connects to the ____________ terminal of the power source and provides the ____________ for the internal and external circuitry.

3. The output pin connects to the external circuit that uses the ____________ version of the input signal.

4. Pins 2 and 6 allow you to set the overall ____________ of the amplifier.

5. When you hold the slide switch of your Intercom in the Talk position, the speaker acts as a ____________.

6. T1 is referred to as a **step-up/step down** transformer because it transforms a low impedance to a high impedance. (circle one)

7. The number of turns in the windings of a transformer are **indirectly/directly** proportional to impedance. (circle one)

8. Diode D1 protects the circuitry against wrong ____________.

Model SK-109

Sound Flasher

Your Sound Flasher picks up ambient sound and, depending upon its amplitude (loudness), affects the brightness of the lamp(s) connected to the output socket. Since the Flasher is extremely sensitive to sound, its effect on the lamps is very random.

When you complete this lesson, you will:

1. Be able to properly connect a typical integrated circuit operational amplifier in a circuit.

2. Be able to properly connect an NPN transistor in a circuit.

3. Understand how pulses can be used to control the brightness of one or more lamps.

4. Understand the theory of a rectifier circuit.

CIRCUIT THEORY

INPUT CIRCUIT

The heart of the input circuit is a type 1458 dual integrated circuit op amp (operational amplifier). As the name implies, there are two op amps in one 8-pin integrated circuit. Integrated circuit operational amplifiers are more stable, have higher gain, and take up less space than a similar transistor amplifier. External support circuitry is only required to control the gain and frequency response.

The input circuit consists of a microphone, two operational amplifiers, and the associated circuitry. The various pins of a typical operational amplifier are described first, followed by an explanation of the external circuitry. NOTE: To avoid confusion, the two operational amplifiers in the integrated circuit will be referred to as A and B.

Refer to Figure 9-1 while you read the following information.

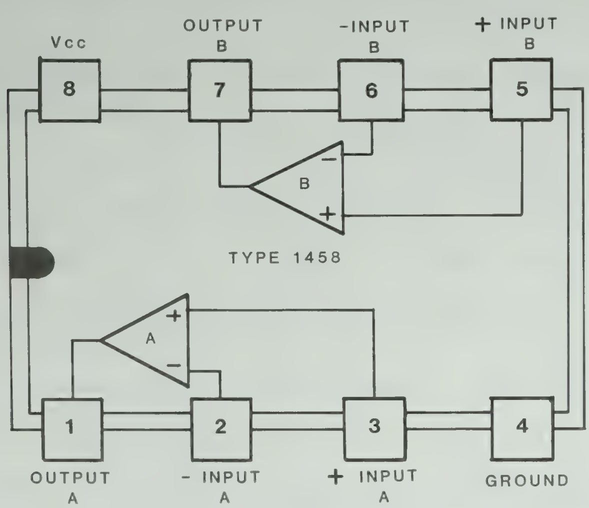


Figure 9-1

NOTE: The following information only applies to the type 1458 integrated circuit. The pin connections, and even the number of op amps in a single package, may be different with other types of op amp ICs.

Pin 1 (A, output) — Connects to the external circuitry that uses the amplified version of the signal applied to one of the inputs.

Pin 2 (A, inverting input) — One input to the op amp. Signals at the output (pin 1) of this op amp will be 180 degrees out of phase with (a mirror image of) the signal applied to this input.

Pin 3 (A, noninverting input) — One input to the op amp. Signals at the output (pin 1) of this op amp will be in phase with the signal applied to this input.

Pin 4 (ground) — Connects to the negative (−) terminal of a power source and the common line of the circuitry. It provides the return for the internal and external circuitry.

Pin 5 (B, noninverting input) — One input to the op amp. Signals at the output (pin 7) of this op amp will be in phase with the signal applied to this input.

Pin 6 (B, inverting input) — One input to the op amp. Signals at the output (pin 7) of this op amp will be 180 degrees out of phase with (a mirror image of) the signal applied to this input.

Pin 7 (B, output) — Connects to the external circuitry that uses the amplified version of the signal applied to one of the inputs.

Pin 8 (Vcc) — Connects to the positive (+) terminal of a power source. It supplies the voltage required by the internal circuitry of the IC.

Refer to Figure 9-2 while you read the following information.

When sound (audio) reaches the microphone (MIC), it then passes through capacitor C1 to the noninverting input of integrated circuit U1A. Since the microphone requires a DC voltage to operate (as indicated by the + and − marks), capacitor C1 passes the audio but blocks the DC so it cannot interfere with the biasing of U1A.

Resistor R1 provides the proper voltage for the microphone, while resistors R2 and R3 set the operating bias for U1A. Resistors R5 and R6 together with capacitors C3 and C4 provide feedback from the output of the IC to the inverting input. This feedback sets the gain of the amplifier. In addition, capacitors C3 and C4 alter the response of the amplifier by rolling off (reducing) the high and low frequencies.

Capacitor C5 couples the amplified audio coming from U1A to control R7, which allows you to adjust the sensitivity of the Flasher. Capacitor C7 then couples the audio to the non- inverting input of the next op amp, U1B, which operates just like U1A. A capacitor is required here to prevent the resistance of the control from interfering with the bias of U1B.

Similar to U1A, resistors R8 and R9 set the operating bias and resistors R12 and R13 together with capacitors C8 and C9 provide feedback for U1B. Capacitor C11 then couples the amplified audio coming from U1B to the switching circuit described next.

Quiz

1. Integrated circuit operational amplifiers are more ____________, have higher ____________, and take up less space than a similar transistor amplifier.

Refer to Figure 9-1 when you answer the following questions.

2. The Vcc pin of the IC connects to the ____________ terminal of a power source and supplies the voltage required by the ____________ circuitry of the IC.

3. The ground pin connects to the ____________ terminal of a power source and provides the ____________ for the internal and external circuitry.

4. The output pin connects to the external circuitry that uses the ____________ version of the signal applied to one of the inputs.

Refer to Figure 9-2 when you answer the following questions.

5. Capacitor C1 passes the ______________ but blocks the ______________ so it cannot interfere with the biasing of U1A.

6. Resistors R2 and R3 set the operating ______________ for U1A.

7. The feedback provided by resistors R5 and R6 and capacitors C3 and C4 sets the ______________ of the amplifier.

8. Control R7 allows you to adjust the ______________ of the Flasher.

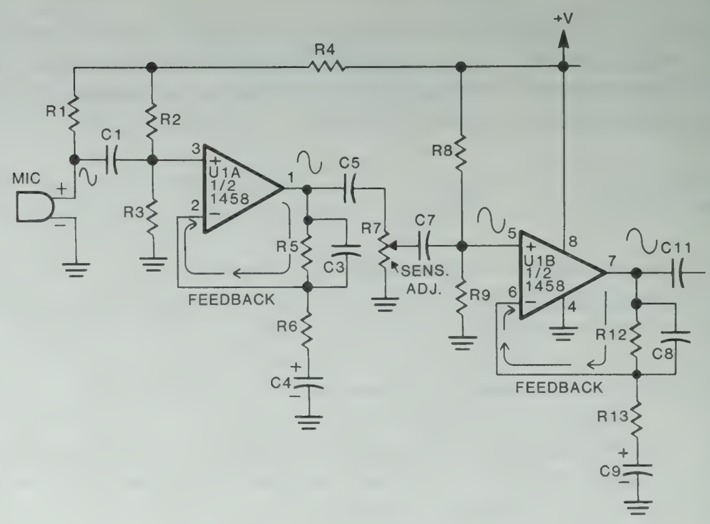


Figure 9-2

SWITCHING CIRCUIT

Refer to Figure 9-3 while you read the following information.

The switching circuit is formed by transistors Q1 and Q2 and the associated circuitry. This circuit generates pulses that are used by the control circuit, which is described later.

Transistors Q1 and Q2 are NPN types, as indicated by the arrow inside the symbol pointing outward. To conduct, the emitter (E) must be negative, the collector (C) positive, and the base (B) slightly (about 0.7 volt) positive.

Resistors R14 and R15 set the operating point of transistor Q1 so that it only responds to the positive portion of a signal applied to its base. When the audio signal coming from the input circuit is applied to the base, the transistor's collector voltage becomes lower during the positive half of the signal on the base. During the negative half of the signal, and when no audio is applied, the collector voltage remains high. Capacitor C12 filters these variations before they are applied to the base of transistor Q2. Resistor R17 and capacitor C13 provide bypassing for the emitter and allow for tolerance variations in the transistor.

When no sound is present the base of transistor Q2 is high, which keeps the transistor saturated and the collector voltage low. When sound is present, however, the base becomes lower and allows the collector voltage to rise. The raising and lowering of the collector voltage is applied to the control circuit described next.

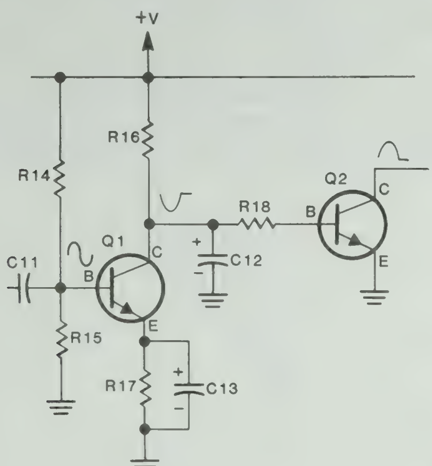


Figure 9-3

Quiz

1. The switching circuit generates ____________ that are used by the control circuit.

2. Draw the symbol of an NPN transistor.

3. For an NPN transistor to conduct, the emitter must be ____________, the collector ____________, and the base slightly (about 0.7 volt) ____________.

Refer to Figure 9-3 when you answer the following questions.

4. When the audio signal coming from the input circuit is applied to the base of transistor Q1, the transistor's collector voltage becomes **higher/lower** during the positive half of the signal. (circle one)

5. When no sound is present, the base of transistor Q2 is **high/low** which keeps the transistor saturated and keeps the collector voltage low. (circle one)

CONTROL CIRCUIT

Refer to Figure 9-4 while you read the following information.

The control circuit is made up of integrated circuit U2, transistors Q3 and Q4, and the associated circuitry. This circuit controls the amount of time that power is applied to the load (lamps), which changes their brightness.

The integrated circuit is a type 555 timer circuit that is connected as an astable (continuous) oscillator. It generates pulses that are applied to the base of transistor Q3. When the voltage on pin 5 is high, the spacing between the pulses is very narrow. In contrast, when the voltage on pin 5 is low, the pulses are much farther apart. Resistors R19 and R21 together with capacitor C15 determine the width of these pulses. NOTE: For detailed information about timer circuits, refer to the SK-102 and SK-105 lessons.

Transistors Q3 and Q4 are connected in a Darlington configuration, which features a high-input impedance and high amplification. These transistors increase the amplitude of the pulses coming from the timer IC so they can control a load that requires a much higher voltage. Each pulse briefly turns transistors Q3 and Q4 on and applies the full power supply voltage to the load. When the pulses are close together, the transistors are on for a longer portion of a given time period. This in turn causes the load lamp(s) to be brighter than when the pulses are farther apart.

During the time when the pulses are close together, the voltage is low and the current is high. When the spacing between the pulses is wider, however, the current is low and the voltage is high. Since voltage and current are inversely proportional, the power in the transistor circuit is negligible.

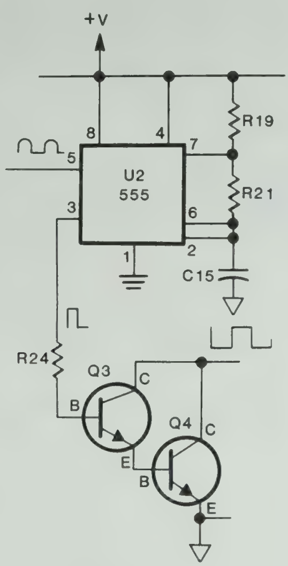


Figure 9-4

Quiz

Refer to Figure 9-4 when you answer the following questions.

1. The control circuit is made up of integrated circuit ________, transistors ________ and ________, and the associated circuitry.

2. The control circuit controls the amount of time that power is applied to the ________.

3. The timer IC generates ________ that are applied to the base of transistor Q3.

4. Transistors Q3 and Q4 increase the size of the pulses coming from the timer IC so they can control a load that requires a much higher ________.

5. When the pulses in the control circuit are close together, the load lamp(s) will be **brighter/dimmer**. (circle one).

POWER SUPPLY CIRCUIT

The main power supply circuit consists of diodes D2 through D4 and the associated circuitry. This circuit converts the AC (alternating current) line voltage into DC (direct current). The remainder of the Flasher circuits all require DC to operate.

Alternating current (AC) flows first one way and then the other way in a circuit, at a certain frequency. Direct current (DC) always flows the same way in a circuit and, therefore, has no frequency.

In the United States, the standard AC line current operates at a frequency of 60 Hertz. Since two alternations form a cycle (or Hertz, Hz), AC changes direction 120 times per second.

Refer to Figure 9-5 when you read the following information.

Diodes D2 through D5 form a full-wave rectifier that converts AC to DC. During the half cycle that AC current is flowing from the top of the rectifier circuit toward the bottom (see Part A of the Figure), it passes through the fuse, diode D3, circuit ground, transistors Q3 and Q4, the load, and back to the line through diode D4. Diodes are "one way" devices that allow current to flow through them in only one direction.

During the next half cycle when the current is flowing in the other direction (see Part B of the Figure), it passes through diode D5, circuit ground, transistors Q4 and Q3, the load, diode D2, and back to the line through the fuse. It is interesting to note that the current always flows through the load in the same direction. Since the junction of diodes D2 and D4 is always positive with respect to ground, it is considered as a DC voltage.

Capacitors C17 through C21 are connected in parallel across the diodes to suppress any noise that may be generated by the diodes.

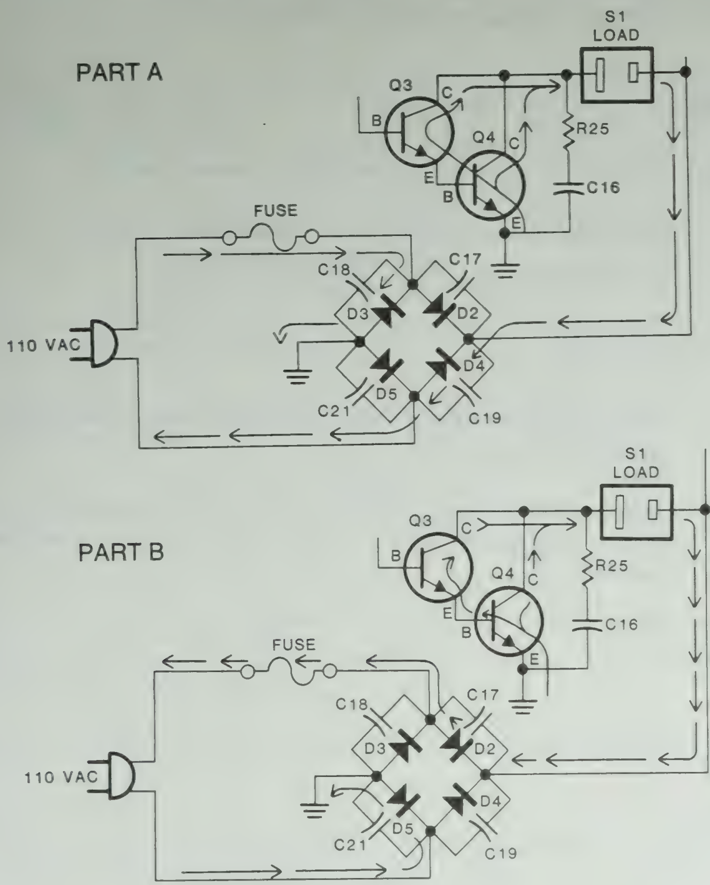


Figure 9-5

NOTE: For more information about power supplies, refer to the SK-101 lesson.

Refer to Figure 9-6 (fold-out from Page 121) while you read the following information.

Resistors R4, R11, R22, and R23, capacitors C2, C6, and C14, and zener diode D1 are also considered to be part of the power supply circuit. Resistors R11, R22, and R23 together with diode D1 reduce the DC voltage coming from the main power supply to a value that is usable by the other Flasher circuits. Capacitors C2 and C6 together with resistor R4 provide filtering for the input circuits.

Quiz

Refer to Figure 9-6 when you answer the following questions.

1. The main power supply circuit consists of diodes ________ through ________ and the associated circuitry.

2. The purpose of the rectifier circuit is to convert ________ into ________.

3. Diodes allow current to flow through them in **one/two** direction(s). (circle one)

4. Capacitors C17 through C21 are connected in parallel across the diodes to suppress any ________ that may be generated by the diodes.

LESSON CHECK

1. Integrated circuit operational amplifiers are more ____________, have higher ____________, and take up less space than a similar transistor amplifier.

Refer to Figure 9-1 when you answer the following questions.

2. The Vcc pin of the IC connects to the ____________ terminal of a power source and supplies the voltage required by the ____________ circuitry of the IC.

3. The ground pin connects to the ____________ terminal of a power source and provides the ____________ for the internal and external circuitry.

4. The output pin connects to the external circuitry that uses the ____________ version of the signal applied to one of the inputs.

Refer to Figure 9-6 when you answer the following questions.

5. The switching circuit generates ____________ that are used by the control circuit.

6. Draw the symbol of an NPN transistor.

7. For an NPN transistor to conduct, the emitter must be ____________, the collector ____________, and the base slightly (about 0.7 volt) ____________.

8. The control circuit controls the amount of time that power is applied to the ____________.

9. When the pulses in the control circuit are close together, the load lamp(s) will be **brighter/dimmer**. (circle one).

10. The purpose of the rectifier circuit is to convert __________ into __________.

11. Diodes allow current to flow through them in **one/two** direction(s). (circle one)

Model SK-110

Speakerphone

Your Speakerphone provides you with hands-free telephone operation. The fast-switching circuitry allows you to hear the caller on the other end of the line and also speak to him. Since the Speakerphone may be set in the middle of a table, group discussion with a caller is possible and convenient.

When you complete this lesson, you will:

1. Understand how bridge rectifiers operate.

2. Be able to describe why the output of a bridge rectifier always has the same polarity, regardless of the voltage applied to it.

3. Be able to describe the purposes of high- and low-pass filters.

CIRCUIT THEORY

The integrated circuit used in your Speakerphone contains a large amount of circuitry that is too technical for this lesson. The various IC pins, therefore, are described briefly, followed by a more detailed description of the external support circuitry.

Refer to Figure 10-1 while you read the following information.

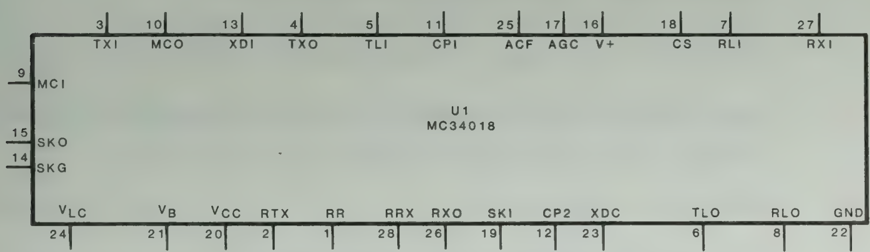


Figure 10-1

Pin 1 (RR) — Provides a reference current for the internal transmit and receive attenuators.

Pin 2 (RTX) — Sets the nominal gain of the transmit attenuator.

Pin 3 (TXI) — Input to the transmit attenuator.

Pin 4 (TXO) — Output of the transmit attenuator.

Pin 5 (TLI) — Input of the transmit level detector.

Pin 6 (TLO) — Output of the transmit level detector.

Pin 7 (RLI) — Input of the receive level detector.

Pin 8 (RLO) — Output of the receive level detector.

Pin 9 (MCI) — Microphone amplifier input.

Pin 10 (MCO) — Microphone amplifier output.

Pin 11 (CP1) — Detects the background noise level.

Pin 12 (CP2) — Detects peak speech signals.

Pin 13 (XDI) — Input to the transmit detector system.

Pin 14 (SKG) — High-current ground for the speaker amplifier output stage.

Pin 15 (SKO) — Speaker amplifier output.

Pin 16 (V +) — DC supply voltage for the IC.

Pin 17 (AGC) — Used to stabilize the speaker amplifier gain control loop and controls the attack and decay time of the circuit.

Pin 18 (CS) — Chip select line.

Pin 19 (SKI) — Input to the speaker amplifier.

Pin 20 (Vcc) — Regulated 5.4-volt DC output that can be used to power external circuitry.

Pin 21 (VB) — Provides 1/2 VCC reference that can be used as an analog ground for the Speakerphone system.

Pin 22 (GND) — Ground pin for the IC.

Pin 23 (XDC) — Transmit detector output.

Pin 24 (VLC) — Volume control input.

Pin 25 (ACF) — Attenuator control filter.

Pin 26 (RXO) — Output of the receive attenuator.

Pin 27 (RXI) — Input of the receive attenuator.

Pin 28 (RRX) — Sets the nominal gain of the receive attenuator.

IMPORTANT: Your Speakerphone is designed to meet Part 68 of the Federal Communications Commission's Rules and Regulations. Do not modify the circuit or change the value of any part. To do so may cause the unit to violate the Rules and Regulations.

GENERAL INFORMATION

The Speakerphone has several functions. It amplifies the signals on the telephone line so they can drive a speaker. In addition, it amplifies the microphone signal to drive the telephone line. The device automatically switches between the transmit and receive signals.

The Speakerphone is connected in parallel with your telephone and it has to be turned off for your regular telephone to operate. The correct way to use the Speakerphone is to use your regular telephone to dial a number and to answer an incoming call. Then, when the connection is made, turn the Speakerphone on.

Each circuit surrounding the integrated circuit will now be described.

POWER SUPPLY

Refer to Figure 10-2 while you read the following information.

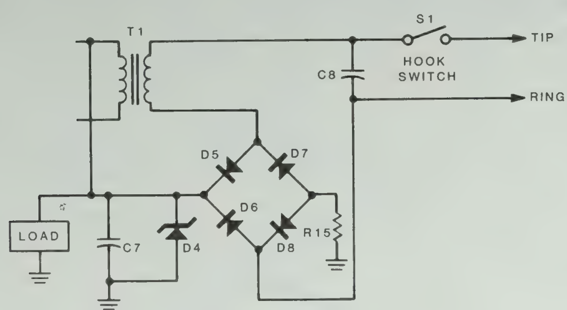


Figure 10-2

The telephone company supplies −48 volts DC on the telephone line at the exchange. This voltage drops to a much lower level by the time it reaches the telephone in your home. The voltage is normally negative at the tip (red wire) and positive at the ring (green wire), but sometimes the voltage is switched for signaling purposes. NOTE: The words "tip" and "ring" refer to the early days of telephone when an operator had to use plugs to manually connect two telephones (the tip being the end contact of the plug and the ring being the other contact).

Transformer T1, diodes D4 through D8, capacitors C7 and C8, and resistor R15 form the power supply circuit. The entire Speakerphone obtains its power from the phone line.

After the line voltage passes through the primary winding of transformer T1, it is applied to one corner of the bridge rectifier formed by dioded D5 through D8. The other side of the line is connected to the opposite corner of the bridge rectifier. Although some other type of rectifier could be used, bridge rectifiers are not affected by the polarity of the line voltage.

If the line voltage has normal polarity (see Figure 10-3), the current passes through diode D7, resistor R15 (ground), the rest of the Speakerphone circuitry, and back through diode D6 to the other side of the line.

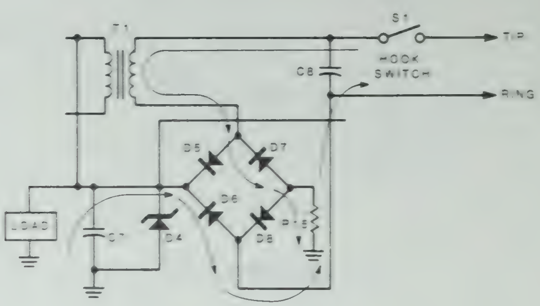


Figure 10-3

If the line voltage is opposite in polarity (see Figure 10-4), the current passes through diode D8, resistor R15 (ground), the rest of the Speakerphone circuitry, and back through diode D5 to the other side of the line. It is interesting to note here that the polarity across the rest of the circuitry (represented as the load) always has the same polarity applied to it.

Capacitor C7 filters the voltage coming from the bridge rectifier, while zener diode D4 holds the voltage at 7.5 volts DC (which is represented by the symbol V+). Zener diode D4 also protects the circuitry against high-voltage transients that may be present on the telephone line. Capacitor C8 also helps reduce transients on the telephone line and resistor R15 limits the current to a safe level.

The V+ voltage from the power supply circuit provides power for the remainder of the Speakerphone circuitry.

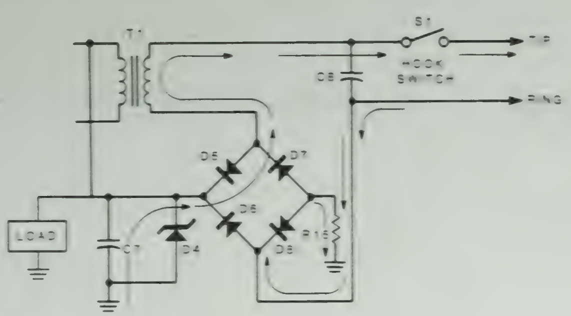


Figure 10-4

Refer to Figure 10-5 while you read the following information.

Integrated circuit U1 provides two regulated output voltages that are derived from the V+ source. 5.4 volts DC is available at pin 20 (represented as Vcc) and 2.9 volts DC is available at pin 21 (represented as VB). Vcc is capable of supplying 3 milliamperes of current, while VB is capable of supplying 1.5 milliamperes. If U1 pin 18, chip select (CS), is connected to V+, Vcc and VB produce zero volts.

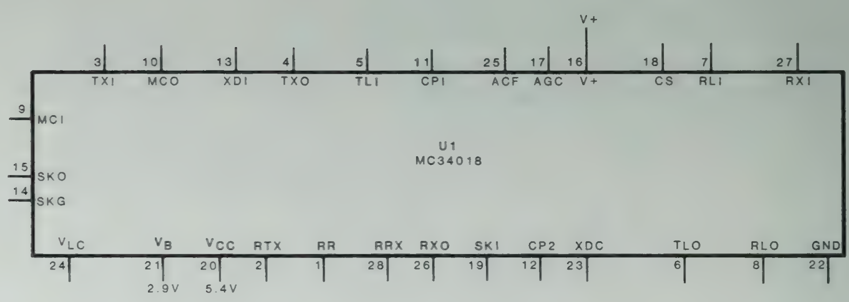


Figure 10-5

Quiz

Refer to Figure 10-2 when you answer the following questions.

1. Diodes D5 through D8 form a ____________ rectifier.

2. A bridge rectifier is used because it **is/is not** affected by the polarity of the line voltage. (circle one)

3. The polarity of the DC voltage that is produced by the bridge rectifier is **always the same/different**. (circle one)

4. Zener diode ____________ holds the voltage coming from the bridge rectifier at 7.5 volts DC.

5. The V+ voltage from the power supply circuit provides power for the ________________.

RECEIVE SIGNAL PATH

Refer to Figure 10-6 while you read the following information.

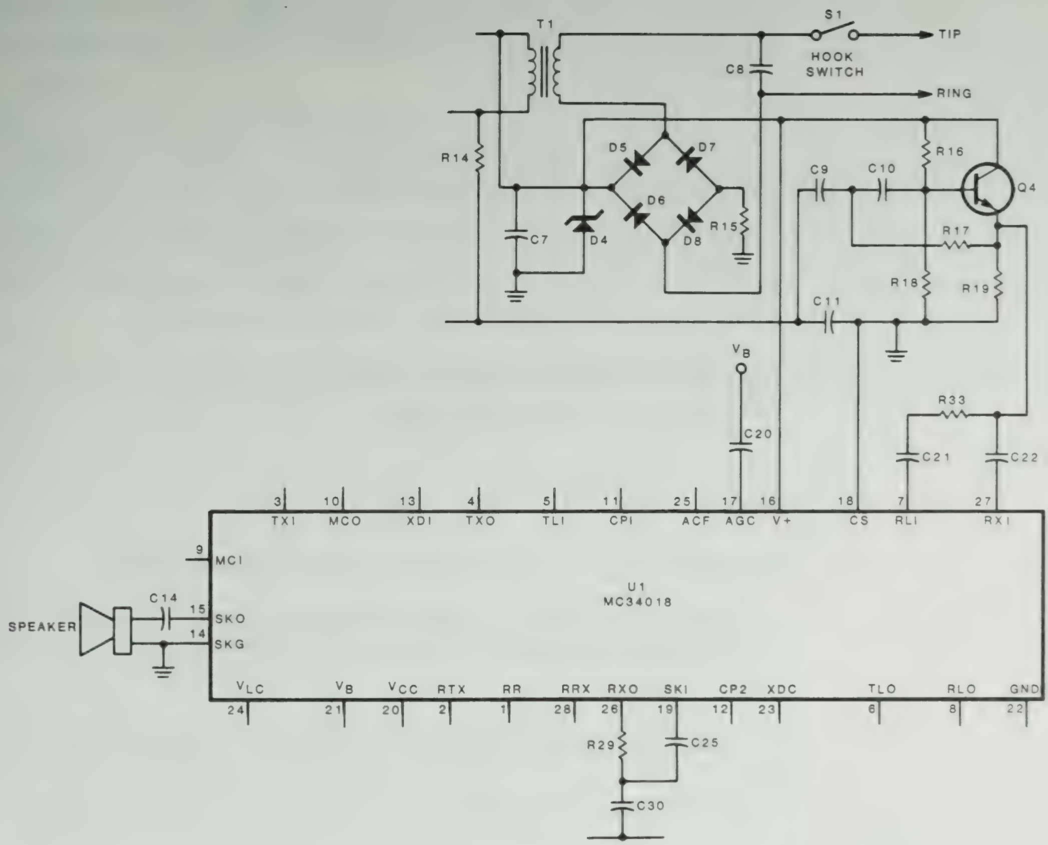


Figure 10-6

The incoming signal from the telephone line is referred to as the "receive signal." This signal is made up of audio signals between 300 and 3000 Hertz.

Transformer T1 together with transistor Q4, part of integrated circuit U1, and the associated components form the receive circuitry. The telephone line signal is coupled through transformer T1, resistor R14, and capacitors C9 and C10 to the base (B) of transistor Q4.

Resistor R14 and capacitor C11 form a low-pass filter to roll off the high frequencies, while capacitors C9 and C10 and resistor R17 form a high-pass filter to roll off the low frequencies. Resistors R16 and R18 provide the proper bias for transistor Q4, which operates as an emitter follower. The signal coming from the emitter (E) is developed across resistor R19. This voltage then passes through capacitor C22 to the RXI input (pin 27) of integrated circuit U1. Pin 27 is the input to an internal attenuator.

The output of the attenuator at pin 26 (RXO) passes through an RC filter formed by resistor R29 and C30, which rolls off the high frequencies. The signal is then coupled through capacitor C25 to pin 19 (SKI), which is the input to the internal power amplifier inside U1. The output of this amplifier at pin 15 (SKO) can deliver up to 100 milliamperes into a 25-ohm speaker. The amplifier contains a peak limiter, which adjusts the gain to prevent it from overdriving the speaker.

Capacitor C20 sets the response time of the peak limiter, while capacitor C14 couples the signal to the speaker.

Quiz

Refer to Figure 10-6 when you answer the following questions.

1. Resistor R14 and capacitor C11 form a **low/high**-pass filter to roll off the **high/low** frequencies. (circle correct answers)

2. Capacitors C9 and C10 and resistor R17 form a **high/low**-pass filter to roll off the **low/high** frequencies. (circle correct answers)

3. Transistor Q4 operates as an ____________ follower.

4. The amplifier inside U1 contains a peak limiter, which adjusts the gain to prevent it from ____________ the speaker.

5. Capacitor __________ couples the signal to the speaker.

TRANSMIT SIGNAL PATH

Refer to Figure 10-7 while you read the following information.

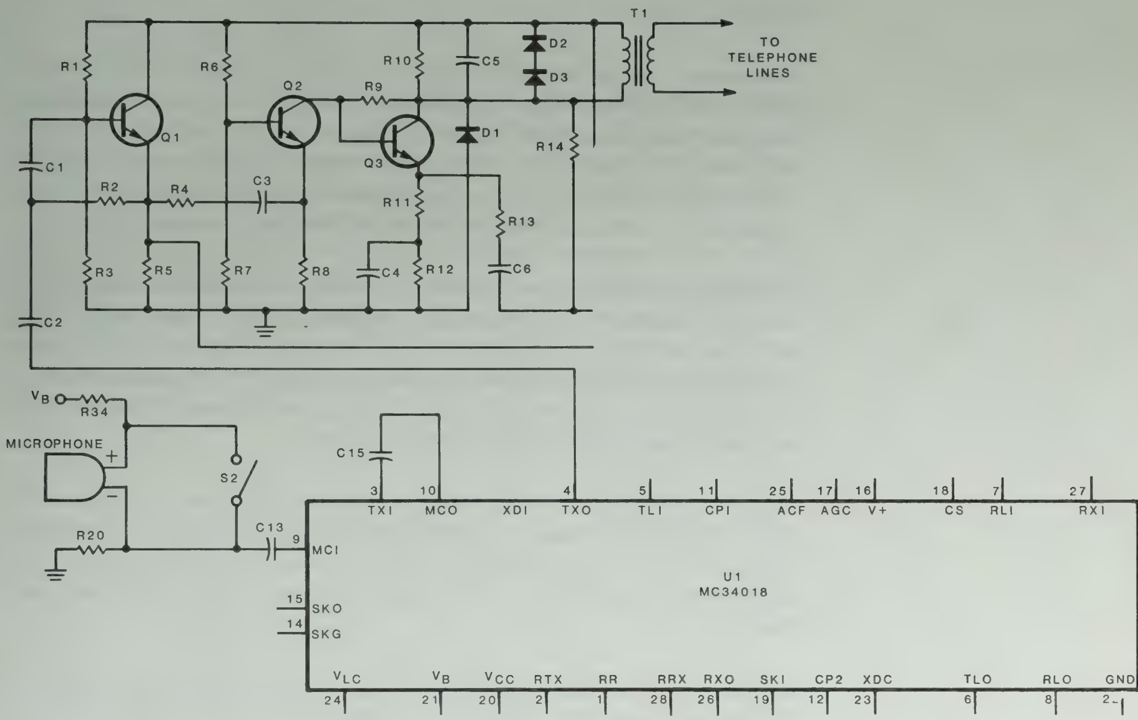


Figure 10-7

The microphone, part of integrated circuit U1, transistors Q1, Q2, and Q3, diodes D1, D2, and D3, transformer T1, and the associated components form the transmit circuitry.

Resistors R34 and R20 limit the current through the microphone, while capacitor C13 couples microphone the audio to the MCI input (pin 9) of U1. Mute switch S2 must be off (open) before the microphone can operate.

A microphone amplifier inside U1 increases the amplitude of the audio signal before it is coupled from the MCO output (pin 10) through capacitor C15 to the TXI input at pin 3. The signal then passes through a transmit attenuator inside U1 and again exits the IC at the TXO output (pin 4).

The signal coming from U1 passes through capacitors C2 and C1 to the base (B) of transistor Q1, which operates in an emitter-follower configuration. Capacitors C2 and C1 together with resistor R2 form a high-pass filter that rolls off the low frequencies. Resistors R1 and R3 bias transistor Q1 for the proper operating point. Resistor R4 and capacitor C3 then couple the signal to the emitter of transistor Q2.

Resistors R6 and R7 bias transistor Q2, which operates in a common-base configuration, for the proper operating point. The signal coming from the collector (C) of Q2 is applied directly to the base of transistor Q3. Resistor R9 sets the operating bias for transistor Q3, while resistors R10, R11, R12, capacitors C4 and C5, and transformer T1 set the gain and the frequency response of this stage.

Capacitor C4 together with resistors R10 and R11 and transformer T1 control the low-frequency gain of the stage, while capacitor C5, resistors R10 and R11, and transformer T1 control the high-frequency gain. Diodes D1, D2, and D3 provide transient protection and limit the signal level.

Resistor R13 and capacitor C6 cancel the signal coming through resistor R14 in the transmit mode. These signals are out of phase, since one comes from the emitter and the other from the collector of transistor Q3. Transformer T1 couples the transmit signal from the collector of Q3 to the telephone lines.

Quiz

Refer to Figure 10-7 when you answer the following questions.

1. Capacitor __________ couples the microphone audio to the MCI input (pin 9) of U1.

2. Mute switch S2 must be **off/on** before the microphone can operate. (circle one)

3. Transistor Q2 operates in a ____________________ configuration.

4. The signals applied to resistor R13 and capacitor C6 are out of phase, since one signal comes from the _____________ while the other signal comes from the _____________ of transistor Q3.

5. Transformer T1 couples the transmit signal from the collector of Q3 to the ____________________.

CONTROL CIRCUITRY

Refer to Figure 10-8 while you read the following information.

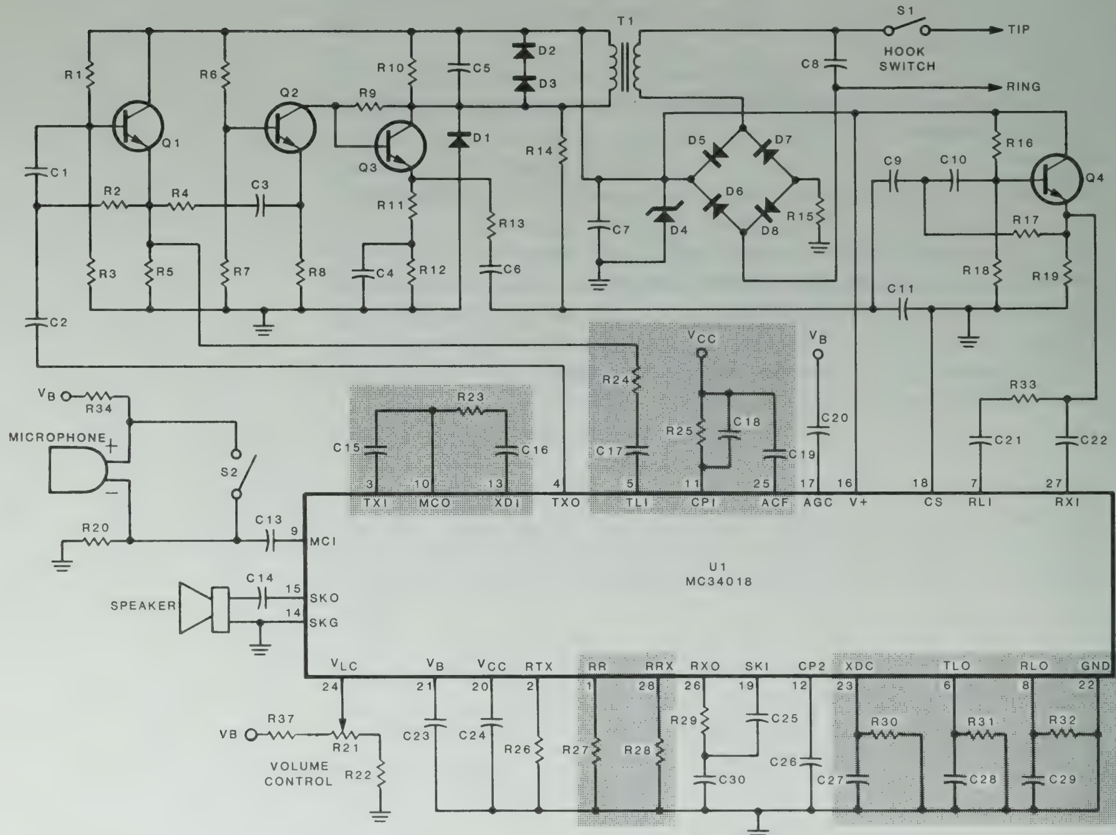


Figure 10-8

The Speakerphone operates in a half-duplex mode. The receiver and transmitter attenuators inside U1 are complementary; when one is at maximum gain, the other is at maximum attenuation.

A control signal from the attenuator control inside U1 is present at pin 25 (ACF). The level of this signal is 6 millivolts in the transmit mode, 75 millivolts in the idle mode, and 150 millivolts in the receive mode. Capacitor C19 filters out any clicks on this control signal.

Control R21 adjusts the volume while resistor R22 limits the range of the volume control. Resistors R26 and R27 set the fixed (resting) attenuation of the transmitter attenuator, while resistors R27 and R28 set the fixed attenuation of the receiver attenuator. The attenuator control obtains its signals from the transmit-receive comparator, the transmit detector, and the DC volume control (pin 24) inside the IC.

In the transmit mode, the microphone audio is coupled through resistor R23 and capacitor C16 to the input of the transmit detector. Resistor R23 sets the sensitivity of the detector, while capacitors C26 (at pin 12) and C18 and resistor R25 (pin 11) set the response time. When there is no signal present, the output of the transmit detector at pin 23 is zero. When sound is present, the voltage on pin 23 goes to approximately 4 volts. This voltage switches the attenuator control to the transmit mode, if the transmit-receive comparator is in the transmit mode. Capacitor C27 and resistor R30 control the decay time at pin 23.

The transmit signal coming from the emitter of transistor Q1 passes through resistor R24 and capacitor C17 to U1 pin 5 (TLI). Resistor R24 limits the current while capacitor C17 couples the audio signal but blocks the DC voltage that is present on the emitter. Capacitor C28 at pin 6 controls the rise time, while resistor R31 controls the decay time of this transmit-control signal. This signal is then applied to the transmit-receive comparator inside the IC.

The receive signal coming from the emitter of transistor Q4 passes through resistor R33 and capacitor C21 to U1 pin 7 (RLI). Resistor R33 limits the current while capacitor C21 couples the audio signal and blocks the DC. Capacitor C29 at pin 8 controls the rise time, while resistor R32 controls the decay time of the receive-control signal. This signal is then applied to the transmit-receive comparator inside the IC.

The output of the transmit-receive comparator is applied to the attenuator control inside the IC to control the transmit and receive attenuators. These attenuators pass the transmitted or the received signal.

Quiz

1. The Speakerphone operates in a ________________ mode.

2. When the transmitter attenuator inside the IC is at maximum gain, the receiver attenuator is at maximum ______________.

Refer to Figure 10-8 when you answer the following questions.

3. In the transmit mode, the microphone audio is coupled through resistor __________ and capacitor __________ to the input of the transmit detector.

4. When there is no signal present, the output of the transmit detector at pin 23 is _________ volts.

5. The output of the transmit-receive comparator is applied to the attenuator control inside the IC to control the ______________ and ______________ attenuators.

LESSON CHECK

Refer to Figure 10-9 when you answer the following questions.

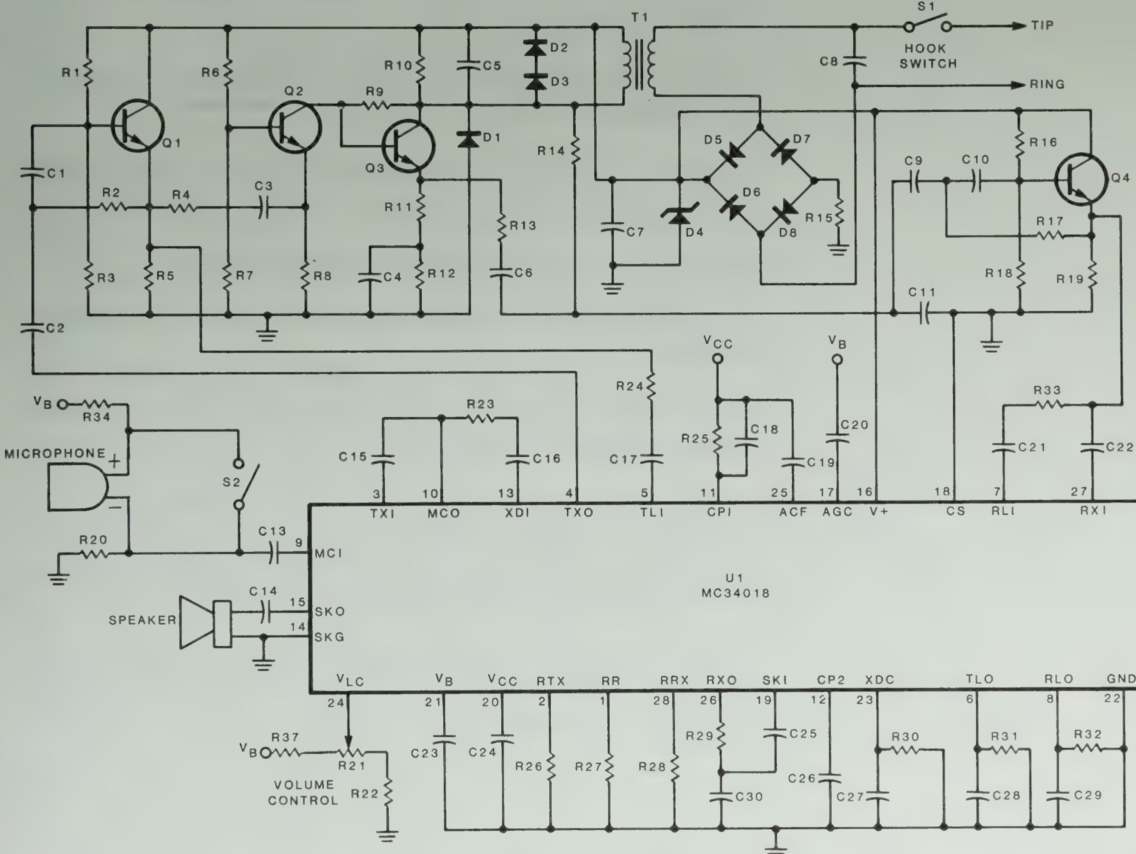


Figure 10-9

1. Diodes D5 through D8 form a __________ rectifier.

2. The polarity of the DC voltage that is produced by the bridge rectifier is always the **same/different**. (circle one)

3. The V+ voltage from the power supply circuit provides power for the __________.

4. Resistor R14 and capacitor C11 form a **low/high**-pass filter to roll off the **high/low** frequencies. (circle correct answers)

5. Capacitors C9 and C10 and resistor R17 form a **high/low**-pass filter to roll off the **low/high** frequencies. (circle correct answers)

6. Capacitor __________ couples the signal to the speaker.

7. Mute switch S2 must be **off/on** before the microphone can operate. (circle one)

8. Transformer T1 couples the transmit signal from the collector of Q3 to the __________.

9. The Speakerphone operates in a __________ mode.

10. When the transmitter attenuator inside the IC is at maximum gain, the receiver attenuator is at maximum __________.

11. The output of the transmit-receive comparator is applied to the attenuator control inside the IC to control the __________ and __________ attenuators.

Model SK-111

AC Sound Switch

Your AC Sound Switch is a sound toggle that can be used to turn a device, such as a light, on and off. The first time the Switch picks up a loud sound (such as a hand clap), it turns the device on. The next time it picks up the loud sound, it turns the device off, etc.

When you complete this lesson you will:

1. Be able to properly connect a typical integrated circuit operational amplifier in a circuit.

2. Be able to properly connect an NPN transistor in a circuit.

3. Be able to describe the operation of a flip-flop circuit.

CIRCUIT THEORY

OPERATIONAL AMPLIFIERS

The heart of the AC Sound Switch is a type 3900 quad integrated circuit op amp (operational amplifier). As the name implies, there are four op amps in one 14-pin integrated circuit. Integrated circuit operational amplifiers are more stable, have higher gain, and take up less space than a similar transistor amplifier. External circuitry is only required to control the gain and frequency response.

Refer to Figure 11-1 while you read the following information.

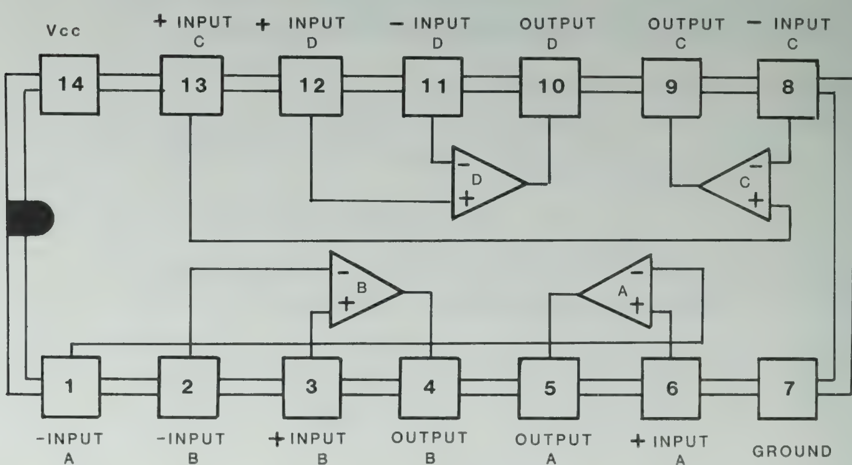


Figure 11-1

NOTES:

1. The following information applies only to the type 3900 integrated circuit. The pin connections, and even the number of op amps in a single package, may be different with other types of op amp ICs.

2. To avoid confusion, the four operational amplifiers will be referred to as A, B, C, and D.

Pin 1 (A noninverting input) — One input to the A op amp. Signals at the output (pin 5) of this op amp will be in phase with the signal applied to this input.

Pin 2 (B noninverting input) — One input to the B op amp. Signals at the output (pin 4) of this op amp will be in phase with the signal applied to this input.

Pin 3 (B inverting input) — One input to the B op amp. Signals at the output (pin 4) of this op amp will be 180 degrees out of phase with (a mirror image of) the signal applied to this input.

Pin 4 (B output) — Connects to the external circuitry that uses the amplified version of the signal applied to one of the B inputs.

Pin 5 (A output) — Connects to the external circuitry that uses the amplified version of the signal applied to one of the A inputs.

Pin 6 (A inverting input) — One input to the A op amp. Signals at the output (pin 5) of this op amp will be 180 degrees out of phase with (a mirror image of) the signal applied to this input.

Pin 7 (ground) — Connects to the negative (−) terminal of a power source and the common line of the circuitry. It provides the return for the internal and external circuitry.

Pin 8 (C inverting input) — One input to the C op amp. Signals at the output (pin 9) of this op amp will be 180 degrees out of phase with (a mirror image of) the signal applied to this input.

Pin 9 (C output) — Connects to the external circuitry that uses the amplified version of the signal applied to one of the C inputs.

Pin 10 (D output) — Connects to the external circuitry that uses the amplified version of the signal applied to one of the D inputs.

Pin 11 (D inverting input) — One input to the D op amp. Signals at the output (pin 10) of this op amp will be 180 degrees out of phase with (a mirror image of) the signal applied to this input.

Pin 12 (D noninverting input) — One input to the D op amp. Signals at the output (pin 10) of this op amp will be in phase with the signal applied to this input.

Pin 13 (C noninverting input) — One input to the C op amp. Signals at the output (pin 9) of this op amp will be in phase with the signal applied to this input.

Pin 14 (Vcc) — Connects to the positive (+) terminal of a power source. It supplies the voltage required by the internal circuitry of the IC.

Quiz

1. Integrated circuit operational amplifiers are more STABLE, have higher GAIN, and take up less space than a similar transistor amplifier.

Refer to Figure 11-1 when you answer the following questions.

2. The Vcc pin of the IC connects to the + terminal of a power source and supplies the voltage required by the INT. circuitry of the IC.

3. The ground pin connects to the — terminal of a power source and provides the RETURN PATH for the internal and external circuitry.

4. The output pins connect to the external circuitry that uses the AMPLIFIED version of the signal applied to one of the inputs.

INPUT CIRCUIT

Refer to Figure 11-2 while you read the following information.

The input circuit consists of a microphone, two operational amplifiers, and the associated circuitry. When a loud sound reaches the microphone, a portion of it is coupled through resistor R3 and capacitor C1 to the inverting input of integrated circuit U1A. Since the microphone requires a DC voltage to operate (as indicated by the + and − marks), capacitor C1 passes the audio but blocks the DC so it cannot interfere with the biasing of U1A.

Resistor R1, in parallel with control R2, provides the proper voltage for the microphone, while resistors R4 and R5 set the operating bias for U1A. The values of resistors R4 and R5, which are connected through R6 to the noninverting input of U1A, are chosen so that the ouput of U1A is normally low. Control R2 allows you to set the sensitivity of the sound switch. Resistors R3 and R7 determine the amount of feedback from the output of the IC to the inverting input. This feedback sets the gain of the amplifier.

Since diodes act like a one-way switch, only the positive part of the amplified sound signal is applied to capacitor C2. This signal quickly charges the capacitor while it is present. When the signal is no longer present, however, capacitor C2 slowly discharges through resistor R8.

The voltage that is present across capacitor C2 is also coupled through resistor R13 to the noninverting input of U1B. Resistor R14 provides positive feedback for U1B so that its output goes high when the input voltage reaches an upper threshold. When the charge on capacitor C2 decreases to a lower threshold, the output of U1B again goes low. It takes about 2 seconds of near silence for the output to return to low. The ratio of resistor R12 to R13 sets the upper threshold, and the ratio of resistor R12 to R14 sets the lower threshold of U1B. The voltage divider formed by resistors R9 and R11 set the reference voltage for this op amp. Op amps that operate in this manner are referred to as Schmitt triggers. The point to remember is that when the input voltage rises above the upper threshold, the output goes high; and when the voltage drops to below the lower threshold, the output returns to low. The output of U1B is coupled to the toggle circuit described next.

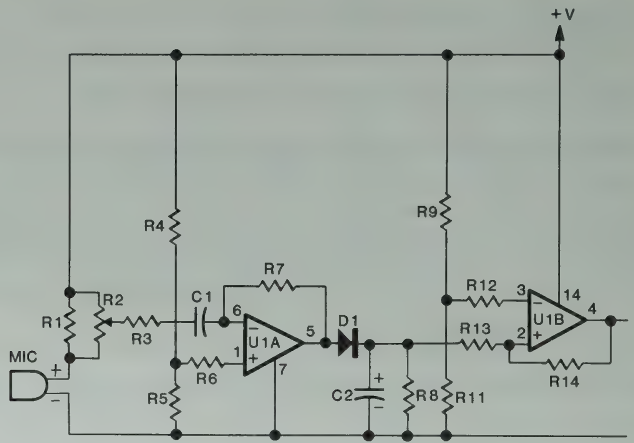


Figure 11-2

Quiz

Refer to Figure 11-2 when you answer the following questions.

1. The values of resistors R4 and R5, are chosen so that the output of U1A is normally **high/low**. (circle one)

2. Control R2 allows you to set the ______________ of the sound switch.

3. Diodes have the characteristic of acting like a ______________ switch.

4. When the input voltage of U1A rises above the upper threshold, the output goes **high/low**; and when the voltage drops to below the lower threshold, the output returns to **high/low**. (circle correct answers)

TOGGLE CIRCUIT

Refer to Figure 11-3 while you read the following information.

Op amps U1C and U1D along with the associated components make up the toggle circuit. A circuit that is connected together in this way (note that the output of each op amp is connected to the inverting input of the other op amp) is referred to as a "flip flop". Due to the way the op amps are connected, the outputs of the two flip flops can never be high at the same time; one output will be high and the other will be low.

Assume that the output of U1D (pin 10) is high and the output of U1C (pin 9) is low. When the output of U1B (in the input stage) goes high, the high is applied through capacitor C3 and resistors R16 and R18 to the noninverting inputs of U1C and U1D. This causes the output of the op amp whose output is low (U1C) to go high. (A high at the noninverting input of the op amp that is already high has no effect.) This high is coupled through capacitor C4 and resistor R15 to the inverting input of U1D, which forces its output to go low. When the next high comes along from U1B, the op amps again change state so that the output of U1C returns to low and the output of U1D goes high. The outputs of U1C and U1D, therefore, flip flop between high and low each time a loud sound arrives at the input of the Sound Switch. The high/low transition is applied to the relay circuit described next.

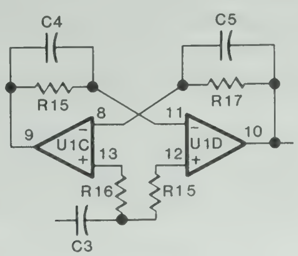


Figure 11-3

Quiz

Refer to Figure 11-3 when you answer the following questions.

1. Op amps U1C and U1D are connected together as a ____________ circuit.

2. Due to the way U1C and U1D are connected, one output will be ____________ and the other will be ____________.

3. When a high is applied to the noninverting input of op amps U1C and U1D, the op amp whose output is low goes **high/low**. (circle one)

4. A high at the noninverting input of the op amp that is ____________ has no effect.

5. The outputs of U1C and U1D flip flop between ____________ and ____________ each time a loud sound arrives at the input of the Sound Switch.

RELAY CIRCUIT

Refer to Figure 11-4 while you read the following information.

Transistor Q1, relay K1, diode D2, and capacitor C9 form the relay circuit. This circuit uses the high/low pulse coming from the toggle circuit to open and close the relay. This in turn either supplies power to or removes power from the external circuit (such as a light).

Transistor Q1 is an NPN type as indicated by the arrow inside the symbol pointing outward. To conduct, the emitter (E) must be negative, the collector (C) positive, and the base (B) slightly (about 0.7 volt) positive.

When the output of U1D in the toggle circuit is low, the base of Q1 is also low and relay K1 is de-energized so its contacts are open. At this time, there is no voltage applied to the external circuit. When the output of U1D is high, however, the high turns transistor Q1 on so that its collector becomes low. Since the relay is now connected across the power supply (described later), it closes its contacts and applies the AC line voltage to the external load.

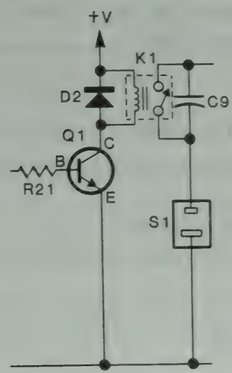


Figure 11-4

Relay coils exhibit a very high "reverse spike" voltage when power is removed due to the collapsing magnetic field. Diode D2 is connected across the relay coil to help protect the other circuitry from becoming damaged by this spike voltage. It is connected across the relay coil so that it acts as a short while the coil is discharging. When the relay is actuated, however, it has no effect. Capacitor C9 is connected across the relay contacts and performs a function similar to that of diode D2. It protects the contacts from any arcing that could occur when the relay opens the external circuit.

Quiz

Refer to Figure 11-4 when you answer the following questions.

1. The relay circuit uses the high/low pulse coming from the toggle circuit to ____________ and ____________ the relay.

2. Draw the symbol of an NPN transistor.

3. For an NPN transistor to conduct, the emitter must be ____________, the collector ____________, and the base slightly ____________.

4. Diode D2 protects the other circuitry from the ____________ voltage that occurs when power is removed from the relay.

5. Capacitor C9 protects the relay ____________ from any spike that could occur when the relay opens the external circuit.

POWER SUPPLY CIRCUIT

Refer to Figure 11-5 while you read the following information.

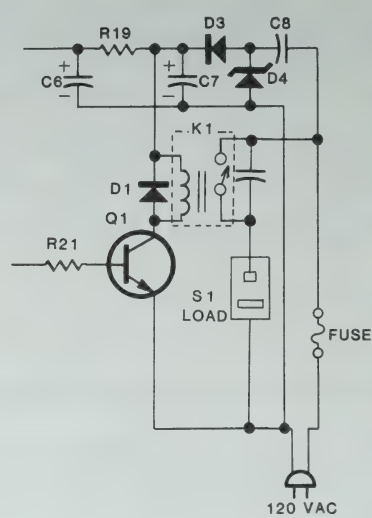


Figure 11-5

The power supply consists of diodes D3 and D4, capacitors C6, C7, and C8, and resistor R19. The main purpose of the power supply is to reduce the AC (alternating current) line voltage and change it into DC (direct current) that can be used to power the other circuits.

Alternating current (AC) flows first one way and then the other way in a circuit, at a certain frequency. Direct current (DC) always flows the same way in a circuit and, therefore, has no frequency.

In the United States, the standard AC line current operates at a frequency of 60 Hertz. Since two alternations form a cycle (or Hertz, Hz), AC changes direction 120 times per second.

Capacitors exhibit reactance instead of resistance. Reactance is similar to resistance, but is frequency sensitive. Capacitor C8, which has a high reactance, is connected in series with the AC line to lower the voltage. One advantage of using a capacitor here is that it can reduce the voltage without the heating effects that a resistor would exhibit.

The external circuitry, when turned on, keeps a load on the power supply so that the voltage drop across C8 would be quite high. When the external circuitry is turned off, however, very little current is drawn by the Sound Switch circuitry and the voltage drop across C8 would be low. Zener diode D4 helps protect the remainder of the Sound Switch circuitry during these low load conditions by keeping a fairly large load across the AC line.

As you learned earlier, diodes act like one-way switches. Diode D3, therefore, only conducts on the positive half of the AC cycle. This results in half-wave rectification of the AC to produce rough DC. Capacitor C7 helps smooth out the rough DC. Resistor R19 and capacitor C6 further filter the DC before it is applied to the input circuitry.

Quiz

1. The main purpose of the power supply is to reduce the ____________ line voltage and change it into ____________ that can be used to power the Sound Switch circuits.

2. AC changes direction 120 times per second, but DC always flows the ____________ in a circuit and has no ____________.

3. Reactance is similar to ____________, but is frequency sensitive.

4. Capacitors can reduce AC voltage without the ____________ effects that a resistor would exhibit.

5. The letters AC stand for ____________ ____________.

LESSON CHECK

1. Integrated circuit operational amplifiers are more ______________, have higher ______________, and take up less space than a similar transistor amplifier.

2. Diodes have the characteristic of acting like a ______________ ______________ switch.

Refer to Figure 11-6 when you answer the following questions.

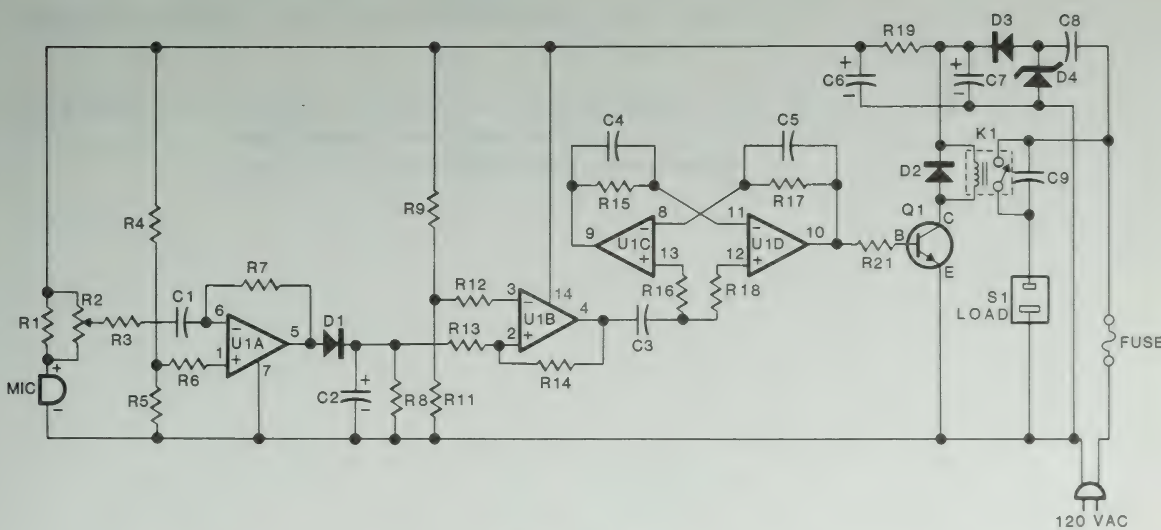


Figure 11-6

3. When the input voltage of U1A rises above the upper threshold, the output goes **high/low**; and when the voltage drops to below the lower threshold, the output returns to **high/low**. (circle correct answers)

4. Op amps U1C and U1D are connected together as a ______________ circuit.

5. Due to the way U1C and U1D are connected, one output will be ______________ and the other will be ______________.

6. The outputs of U1C and U1D flip flop between ____________ and ____________ each time a loud sound arrives at the input of the Sound Switch.

7. Draw the symbol of an NPN transistor.

8. For an NPN transistor to conduct, the emitter must be ____________, the collector ____________, and the base slightly ____________.

9. The main purpose of the power supply is to reduce the ____________ line voltage and change it into ____________ that can be used to power the Sound Switch circuits.

6. The outputs of U1C and U1D flip flop between __________ and __________ each time a loud sound arrives at the input of the Sound Switch.

7. Draw the symbol of an NPN transistor.

8. For an NPN transistor to conduct, the emitter must be __________, the collector __________, and the base slightly __________.

9. The main purpose of the power supply is to reduce the __________ line voltage and change it into __________ that can be used to power the Sound Switch circuits.

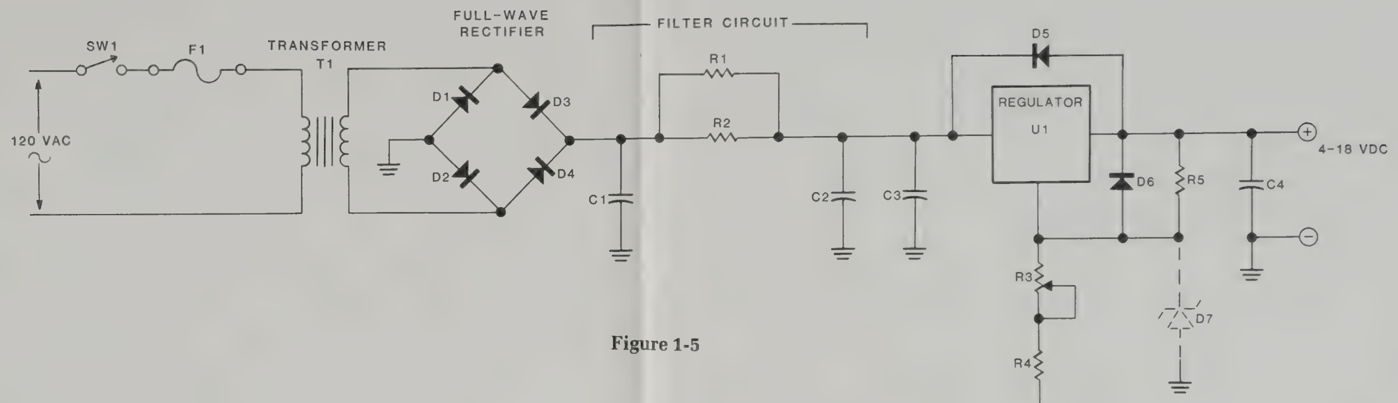


Figure 1-5

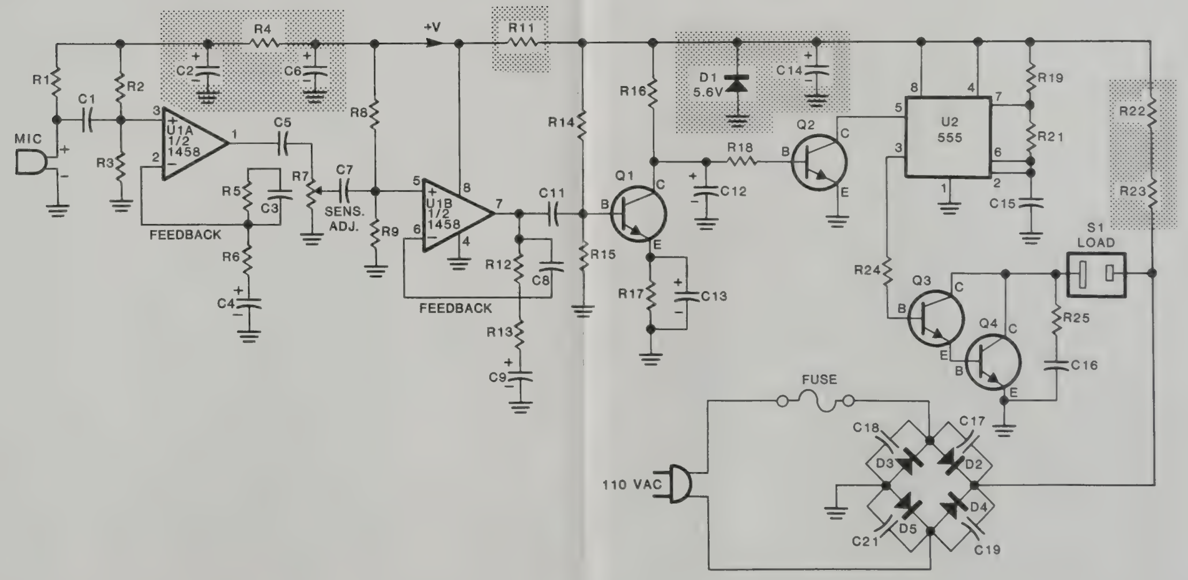
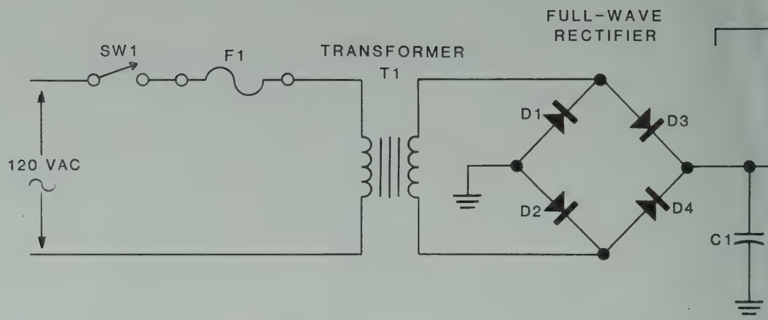
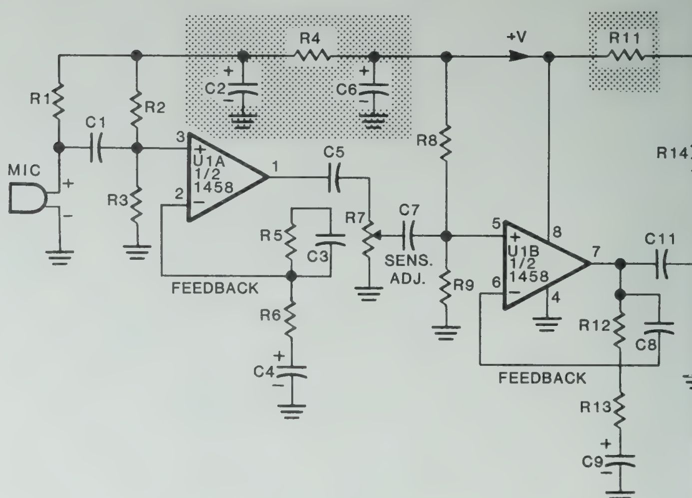


Figure 9-6


FULL-WAVE
RECTIFIER
SW1
F1
TRANSFORMER
T1
120 VAC
D1
D3
D2
D4
C1

Figu


R4
+V
R11
R1
C1
R2
C2
C6
R8
R14
MIC
3
U1A
1/2
1458
1
C5
2
R3
R5
C3
R7
C7
SENS.
ADJ.
R9
5
U1B
1/2
1458
8
7
C11
6
4
FEEDBACK
R6
C4
R12
C8
FEEDBACK
R13
C9

Fig

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